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CORRELATION BETWEEN RATE AND EFFICIENCY OF GAIN IN STEERS

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THE ANIMAL husbandman has generally assumed that there is always a high correlation between rate and efficiency of gain, since this correlation appeared to be a biological necessity. Actually, under certain conditions, this correlation may be relatively low. It is the purpose of this paper to show an exception to this close relationship and that studies or comparisons of gross efficiency may be misleading under certain conditions.

Data from the literature indicates that the correlation is not always high. Winters and McMahon (1933) reported a correlation of 0.34 between rate and efficiency of gain. However, when these data were corrected for mean live weight, the correlation became 0.71. Black and Knapp (1936) reported a correlation of 0.88. Knapp *et al.* (1941) reported a correlation of 0.44. A study of the above experiments indicates that a correlation of 0.50 or less may be expected when all animals are fed the same period of time but when time is variable the correlation is high.

In a recently completed test, 66 steers were fed individually for a 273-day period. After the steers were weaned they were placed in individual stalls and fed ad libitum a ration consisting of a grain mixture and alfalfa hay. The steers were sired by 9 bulls and 6 to 8 progeny from each bull made up each sire group.

The correlation between observed rate and gross efficiency of gain was 0.49. This correlation indicates a relatively high error in selection for efficiency based on rate of gain. The initial weights of the steers varied from 298 to 492 pounds and the final weights from 759 to 1134 pounds. The gain in the feed lot varied from 1.42 pounds to 2.48 pounds per day. The lot means of rate and efficiency showed a low relationship. The fastest gaining sire group was the most efficient. The next fastest gaining group was next to the poorest in efficiency. The slowest gaining lot was fourth in efficiency. Except for the fastest gaining group, none were in the proper rank of efficiency.

Titus *et al.* (1934) proposed a method of analysis with chickens that makes possible a correction of efficiency of each individual to any mean weight. This method, used by Lambert *et al.* (1936) for comparisons of efficiencies of individual steers, is based on the curve of diminishing increment described by Spillman and Lang (1924). The equation of this curve expresses

[1] U. S. Range Livestock Experiment Station, Miles City, Montana.

with a high degree of accuracy the relationship between live weight and feed consumption.[2] The first derivative of this equation is the equation of a straight line regression, and can be written DW/DF equals $KA-KW$.[3] Substituting E for DW/DF and C for KA, this equation then becomes E equals $C-KW$.

The application of this method to two steers will illustrate the principles involved and show the treatment for all steers. Steers No. 25 and 35 were selected because they were about equal in observed gross efficiency. Table 1 shows the observed data on these steers. Steer No. 25 had the heaviest

TABLE 1. OBSERVED DATA ON TWO RECORD OF PERFORMANCE STEERS AT THE U. S. RANGE LIVESTOCK EXPERIMENT STATION

Steer No.	Initial weight	Final weight	Total gain	Daily gain	T.D.N. consumed	Observed efficiency
	pounds	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
25	459	982	523	1.92	3134	16.69
35	397	786	389	1.42	2307	16.86

initial and final weights, made more gain with the higher daily gain, ate more feed and was slightly less efficient than the other steer. It is obvious that comparisons of observed gross efficiencies are misleading. In figure 1, the results of application of the Titus method of analysis are shown. The observed efficiencies are shown by an $\times$ and the initial and final weights of the two steers are marked by lines. Steer No. 25 was more efficient than steer No. 35 at any weight. For example at 700 pounds the corrected efficiency of steer No. 25 was 18.39 and of steer No. 35 was 14.80. At 500 pounds weight, the efficiencies would be 22.49 and 19.00. Thus, it is observed that the faster gaining steer was the more efficient at any weight but because the faster gaining steer was heavier throughout the 273-day feed period, the observed gross efficiency was reduced and therefore misleading. In these animals, the regression coefficient (K) was approximately equal and the lines are parallel. This is not always true.

This method of correction was applied to each of the 66 steers and the corrected efficiency at 700 pounds weight was calculated. The correlation between daily gain and this corrected efficiency of gain was found to be 0.83. Thus, it would seem that daily gain may be used with a high degree of accuracy to predict efficiency of gain at comparable weights but not to predict observed gross efficiency. It is interesting to note that there were sig-

[2] The curve of diminishing increment may be written W equals $A-B_0^{-KF}$.

[3] DW/DF is efficiency of gain (E) and C may be substituted for KA.

nificant differences in the regression coefficients (K) between the progeny of different sires.

In record of performance studies, it is sometimes desirable to feed all animals for a standard length of time. This is true at Miles City where distance makes it impossible to market the steers as they individually reach a required weight. In experiments of this type, comparisons of observed gross efficiencies are misleading and likely to lead to selection of lighter, poorer-gaining steers. The uncorrected and corrected efficiencies and the relation-

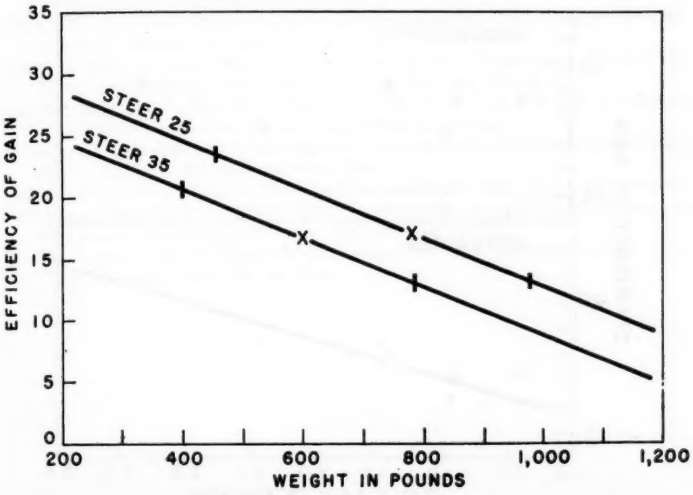

Figure 1. Regression of efficiency of gain with increase in live weight for steer No. 25 and 35. The initial and final weights for each steer are shown by lines and the observed efficiency by an X.

ship with daily gain for the 9 sire groups at Miles City are shown in figure 2. There is little relationship in the group means before correction. The best 4 groups in observed gross efficiency made the best to the poorest in daily gain. When corrected the relation becomes very high between daily gain and corrected efficiency. Kleiber (1936) stated that use of absolute rate of gain as an index to efficiency is applicable only to animals of the same size. This statement is proven in the above analysis. The suggestion of Black and Knapp (1936) that all steers be fed from 500 to 900 pounds in order to measure efficiency is in accord with these findings.

The results of this study are also applicable to general feeding experiments with beef cattle. There are in the literature innumerable instances where

greater rate of gain was noted with one feed yet the feed requirements per 100 pounds of gain may slightly favor the other feed. For example, in a Minnesota report (Peters, 1933) on a comparison of shelled corn and alfalfa hay versus shelled corn, linseed meal and alfalfa hay, the steers receiving linseed meal made .25 pound per day greater gain than those not receiving the meal, yet the pounds of concentrates to produce 100 pounds of gain were 596 pounds and 574 pounds, respectively.

In any comparison, between two individuals or two groups where one

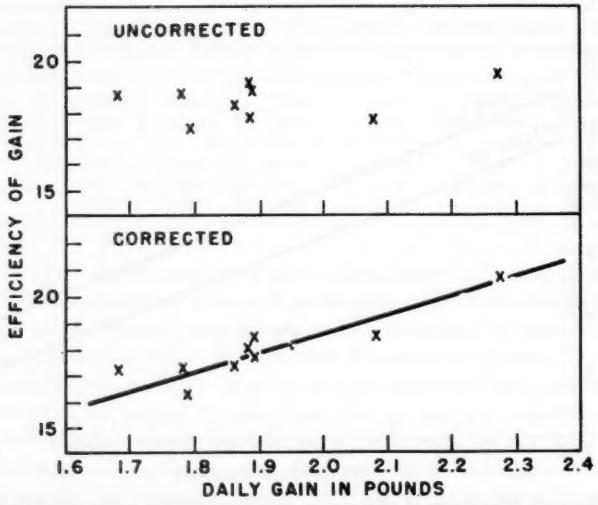

Figure 2. Relationship between rate and uncorrected efficiency of gain for the 9 sire groups and between rate and corrected efficiency of gain for the same sire groups.

animal or group outgains the other during a period of time, a comparison of efficiencies of gain will be misleading. A thorough study of some of the feeding results using this method may revise some of the estimates of values of different feeds.

Conclusions

The following conclusions can be made from this analysis:

1. The high correlation between rate and efficiency of gain is reduced in time-constant populations and this high correlation is applicable only between animals of the same size.

2. Comparisons of gross efficiency should be made only between animals of the same size.

3. Selections on gross efficiency in time-constant feeding periods are generally misleading and often erroneous.

4. In time-constant feeding tests, selections should be made for rate of gain rather than observed gross efficiency.

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THE RELATIONSHIP OF FEEDER GRADE, INITIAL WEIGHT, TOTAL GAIN, FINISHED GRADE, AND CARCASS GRADE OF LAMBS[1]

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Introduction

IT IS common practice to grade feeder animals according to their anticipated outcome in the feed lot. For lambs the standard of excellence has been based largely upon their feeder grade and weight at the time they are placed in the feed lot. Price differentials large enough to be important to feeders often exist between the various grades and weights of feeder lambs. This paper presents a study on the interrelationships between feeder grade, initial weight, total gain, finished grade, and carcass grade as they existed in lambs fed cooperatively by the Experiment Station of South Dakota State College, the Bureau of Animal Industry, and the Bureau of Plant Industry at the U. S. Belle Fourche Field Station, Newell, South Dakota.

Review of Literature

The relationship of feeder grade, weight, total gain, etc. to production in meat animals has received only a limited amount of study. The only other published studies with lambs known to the author are those of C. L. Cole and James C. Foster. Cole correlated growth and body measurements to carcass value and concluded "there was a tendency for the more 'typy' lambs to gain more rapidly than the poor type lambs, but when predicting average daily gains there are single measurements of greater importance." Foster found correlation coefficients of 0.090 and 0.066 between initial weight and gain in two of the samples of feeder lambs he studied.

Source and Kind of Data

The data used in this study were collected from lambs fed during 11 feeding seasons, 1932–43 inclusive. A total of 8,494 head were fattened during the period. Except for a few lots, the lambs were fed in groups of 100 each in open pens on rations consisting of one or more grains, a legume hay, one or more beet by-products, and with and without protein supplements and minerals. All rations fed were adequate to produce satisfactory gains except those composed of grain and non-leguminous roughages fed during the 1935–

[1] Approved for publication by the Director of The South Dakota Agricultural Experiment Station as Journal Series No. 184..

[2] Acknowledgement is made to D. A. Spencer of the U. S. Bureau of Animal Industry for suggestions in interpretation of results.

36 and 1936–37 seasons. However, only 625 of the 8,494 lambs fed were finished on these rations. The average final lot weight of the lambs finished on the grain and non-leguminous roughages was 92 pounds as compared to 98 pounds for all others. The beginning average weight of all lambs was 67 pounds.

The feeder and finished live-animal grades were made by experienced livestock specialists representing the South Dakota Agricultural Experiment Station and the United States Department of Agriculture. In those years in which two or three men rated the lambs, only average rating scores were used. All live-animal scores were made on the basis of prime or fancy select, choice, good, medium, common and cull grades with plus and minus deviations within each, thus making a total of 18 classes. For this study these classes were coded from 0 to 17, 17 being "High Prime" or "High Fancy Select." The weights used were single day weights taken to the nearest pound. Two independent sets of grades were made on each carcass. These grades were made by official B.A.E.[3] and packer graders, B.A.E. graders followed the standard used in A. H. Form 404 of the Bureau of Animal Industry, United States Department of Agriculture. Packer graders used their own grading systems. These varied slightly with different packers but were essentially uniform and coded readily into values similar to those used by B.A.E. graders. It was noticeable, however, that packer graders did not spread the carcasses into as many grades as did B.A.E. graders.

Findings

Two types of management were practiced during the period studied. Throughout the first eight years all lots of lambs were started and finished concurrently, the finishing date being that at which the entire group averaged from 95 to 100 pounds in the feed lot. During the last three years the lots were "topped out" and the lambs marketed in two or three shipments according to the finish of the individuals. Thus it has been necessary to divide the data into two groups as it is obvious that such management would greatly affect the relationship between certain of the measurements studied.

Table 1 shows the 15 correlation and regression coefficients for the six measurements studied under both types of management. Both correlation coefficients and regression coefficients were calculated on an intra-lot basis.

During the period in which all lambs were marketed at one time the correlation coefficients ranged from a -0.06 (initial weight and packer grade) to a 0.54 (initial weight and feeder grade). All coefficients were statistically significant except the one between gains and packer carcass

[3] Bureau of Agricultural Economics, United States Department of Agriculture.

grades. The correlations involving initial weight, feeder grade, finished grade and B.A.E. detailed carcass grade were all moderately large. However, the maximum portion of the total variance accounted for by the independent variate in any of the comparisons was only 29 percent (initial weight accounted for approximately 29 percent of the variance in feeder grade). Total gain was slightly correlated with initial weight and feeder grade and substantially correlated with finished grade and B.A.E. detailed carcass grade. The packer gross carcass grade was only slightly correlated with any of the measurements.

TABLE 1. RELATIONSHIPS[1] BETWEEN INITIAL WEIGHT, FEEDER GRADE, TOTAL GAIN, FINISHED GRADE, AND CARCASS GRADE OF LAMBS

Measurements		Lambs all sold at one time			Lambs sold as finished		
x (Independent)	y (Dependent)	Number of lambs	r	by.x	Number of lambs	r	by.x
Initial weight	feeder grade	4627	.54†	.12†	2256	.69†	.11†
Initial weight	total gain	4633	.09†	.10†	2256	−.43†	−.39†
Initial weight	finished grade	3981	.40†	.09†	2254	.29†	.05†
Initial weight	B.A.E. carcass grade	4580	.35†	.07†	2167	.28†	.06†
Initial weight	packer carcass grade	2578	−.06†	−.01†	2189	−.08†	−.02†
Feeder grade	total gain	4628	.03*	.17*	2256	−.35†	−2.00†
Feeder grade	finished grade	3976	.45†	.44†	2254	.27†	.29†
Feeder grade	B.A.E. carcass grade	4577	.39†	.34†	2166	.29†	.39†
Feeder grade	packer carcass grade	2575	.06†	.06†	2189	−.04	−.04
Total gain	finished grade	3981	.43†	.08†	2254	.15†	.03†
Total gain	B.A.E. carcass grade	4581	.40†	.07†	2166	.08†	.02†
Total gain	packer carcass grade	2578	.02	.003	2189	.16†	.03†
Finished grade	B.A.E. carcass grade	3941	.53†	.48†	2165	.48†	.61†
Finished grade	packer carcass grade	1947	.12†	.09†	2188	.20†	.21†
B.A.E. carcass grade	packer carcass grade	2547	.26†	.30†	2154	.32†	.27†

[1] In this paper an asterisk (*) or the word "significant" has been used to indicate that the value would occur by chance in not more than 5 or less than 1 percent of the trials. A dagger (†) or "highly significant" indicates a value that would occur by chance in less than 1 percent of the trials.

"Topping out" the lots and marketing the lambs as they became finished changed the significantly positive correlations between initial weight and total gain, and between feeder grade and total gain to significantly negative correlations. This shift is logical since such management would not allow the heaviest lambs, which were also slightly superior in type, to make an average total gain and would force the lightest lambs, which were slightly inferior in type, to stay in the feed lot and gain more than an average amount. Marketing the lambs as they finished also tended to reduce the cor-

relation coefficients between initial weight and finished grade, initial weight and carcass grade, feeder grade and finished grade, feeder grade and carcass grade, total gain and finished grade, and total gain and carcass grade. The pooled standard deviations of finished grade, B.A.E. detailed carcass grade, and packer gross carcass grade were not changed by "topping out" the lambs. That of carcass weights, however, was reduced from 6.40 pounds to 5.13 pounds.

The cause of the lack of relationship between packer grades and the other

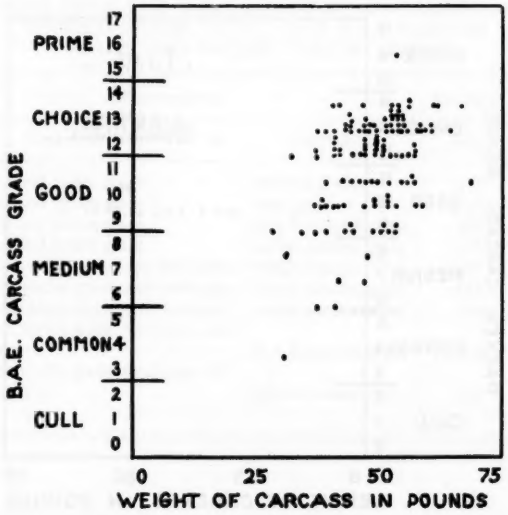

Figure 1. Diagram of relationship between carcass weight and B.A.E. carcass grade in a random sample of lambs fed corn and alfalfa hay.

measurements is not apparent within the data. It is conceivable that some otherwise desirable carcasses may have been too heavy for the packers but an analysis of the data does not show this to exist. For instance during the period studied the carcasses averaged only 48.5 pounds. Also, the correlation between B.A.E. carcass grades and carcass weights and between packer carcass grades and carcass weights were 0.55 and 0.07 respectively, which is similar to the relationship existing between the two different carcass classifications and the other characteristics studied. Partial correlation coefficients between feeder grade and B.A.E. carcass grade, and between feeder grade and packer carcass grade with initial weights held constant were 0.09 and

0.25 respectively. The increase in the correlation coefficient between feeder grade and packer carcass grade due to holding initial weight constant (0.06 to 0.09) is not statistically significant. The decrease in the correlation coefficient between feeder grade and B.A.E. carcass grade under similar treatment (0.39 to 0.25) is highly significant. Therefore, it appears that although weight had a somewhat favorable effect upon B.A.E. carcass grades it had neither favorable nor unfavorable effect upon packer carcass grades. This is exemplified in figures 1 and 2 where carcass grades and carcass

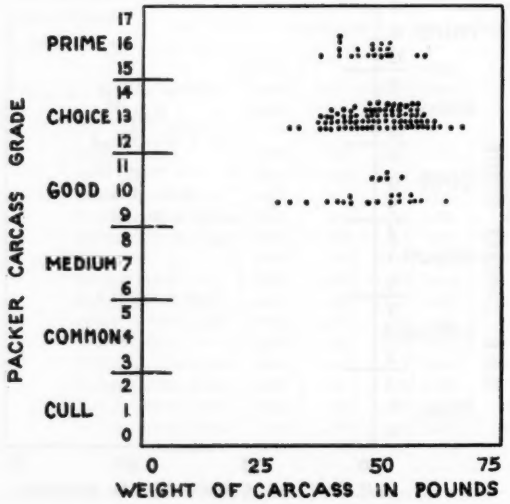

Figure 2. Diagram of relationship between carcass weight and packer carcass grade in a random sample of lambs fed corn and alfalfa hay.

weights of a random sample of lambs are shown graphically. The only logical explanation that occurs to the author for the lack of relationship between the packer grades and the other measurements is that the discrimination and confinement to precise factors of form and finish by packer graders was not sufficient to reveal the differences found by the B.A.E. graders.

The regression coefficients in table 1 show the units of progress possible in the dependent variables for each unit of increase in the independent variables. Thus they show what the rancher and feeder could expect to accomplish by any selection or management changes which would alter the average value of the independant variables. In general, the advantages from

considering any of the measurements were small but positive. An increase of one pound in initial weight resulted in a gain of 0.04 (.12 × ⅓ since initial weight was compared to ⅓ of a feeder grade) of one feeder grade, 0.10 of a pound of total gain, 0.03 of one finished grade, and 0.02 of one B.A.E. carcass grade. An increase in one feeder grade resulted in 0.51 (3 × .17 since the feeder grade unit compared was only ⅓ of a feeder grade) of a pound of total gain, 0.44 of one finished grade, 0.34 of one B.A.E. carcass grade, and 0.06

TABLE 2. MULTIPLE CORRELATIONS INDICATING VALUE OF USING MORE THAN ONE CHARACTERISTIC FOR PREDICTING FINISHED GRADE, TOTAL GAIN, B.A.E. CARCASS GRADE, AND PACKER CARCASS GRADE[1]

Measurements		Lambs all sold at one time	Lambs sold as finished
Independent	Dependent		
Initial weight and feeder grade	finished grade	.51†	.29†
Initial weight and feeder grade	total gain	.09†	.45†
Initial weight and feeder grade	B.A.E. carcass grade	.38†	.32†
Initial weight and feeder grade	packer carcass grade	.10†	.09†
Initial weight, feeder grade, and total gain	finished grade	.65†	.41†
Initial weight, feeder grade, and total gain	B.A.E. carcass grade	.53†	.40†
Initial weight, feeder grade, and total gain	packer carcass grade	.10†	.17†
Initial weight, feeder grade, total gain, and finished grade	B.A.E. carcass grade	.59†	.53†
Initial weight, feeder grade, total gain, and finished grade	packer carcass grade	.19†	.26†

[1] The multiple correlation coefficients are not directly comparable to the simple correlation coefficients in Table 1 as there were only 1922 individuals in the group that were all sold at one time and only 2153 head in the group that were sold as finished.

of one packer carcass grade. An increase in one pound of total gain gave an increase of 0.03 of one finished grade, 0.02 of one B.A.E. carcass grade, and practically no increase in packer carcass grade. Similarly, an increase of one finished grade resulted in a gain of 0.48 of one B.A.E. carcass grade and 0.09 of one packer carcass grade.

The advantage of using more than one measurement in estimating finished grade, gains, and carcass grades is shown by the multiple correlation coefficients in table 2. In the majority of the comparisons the advantage gained was small. The increases in the size of the multiple correlations over those of the simple correlations were negligible for all comparisons involving initial weight and feeder grade with the other measurements. Practically no advantage was gained by using several characters in the place of one to estimate packer grade. Moderate increases in the correlation coefficients

resulted when correlating initial weight, feeder grade and gains with finished grade and with B.A.E. carcass grade, and when correlating initial weight, feeder grade, gains, and finished grade with B.A.E. carcass grade. In general however, it would seem impractical to use other than feeder grade or initial weight in estimating either finished grade or carcass grade previous to the end of the fattening period, or to use other than finished grade for estimating carcass grade at the close of the fattening period.

Another point of practical interest to the feeder concerns the means of the feeder, finished, and carcass grades. Considering only those lambs upon which feeder, finished, B.A.E. carcass, and packer carcass grades were available (4075 head) the following average grades existed: feeder grade, 9.8 or "Good"; finished grade, 12.4 or "Low Choice"; B.A.E. carcass grade, 11.2 or "High Good"; and packer carcass grade, 12.7 or "Choice." Thus it is apparent that the fattening process raises the finished grade and carcass grade of feeder lambs. A feeder, therefore, can expect to market fat lambs properly finished of approximately one grade higher than those he put into the feed lot at the beginning of the fattening period. However, not all lambs increased in grade uniformly. Those lambs thought to be best at the beginning of the feeding periods were less superior to the average at the close of the trials and those thought to be poorest when the feeding began were not so inferior when the feeding ended. In general, lambs that graded 6 points below average (2 full grades) at the beginning graded only 2.64 points below average when finished. Similarly, lambs that graded 6 points above average at the beginning graded only 2.64 points above the average of the group when marketed.

Discussion

The lack of agreement between packer carcass grades and all other measurements studied including B.A.E. carcass grades complicates conclusions that might be drawn from this study. If it could be assumed that the B.A.E. carcass grades which were based on definite and exact physical standards represent the true value of the carcasses studied, the relationship of initial weight, feeder grade, gains, and finished grade to the end product in lambs would be similar to that found in other types of farm livestock and producers could be assured that consideration of such in a production program would result in an improved end product. If, however, packer carcass grades represent the true value of the carcasses, and it would seem that much argument might be presented to substantiate this assumption since packers are selling daily on the basis of their grades, then there is little or nothing to be gained by consideration of the above measurements since almost as many choice packer carcasses came from the poorer feeder lambs as from the superior

ones. Considering the above differences in the two sets of carcass grades, it seems that there is a need for a standardized lamb carcass grading system that could be followed by market participants. Only through the development and general acceptance of a definite standard of carcass perfection and the use of such standard in purchase of live animals can producers be encouraged to exert maximum effort in the production of higher grade lamb carcasses. That such a standard could be successfully developed and used is indicated by the relationship between present feeder grades, finished grades, and B.A.E. carcass grades which have been developed by following definite physical standards.

From the data of this study it was impossible to determine the grade of lambs that were most profitable to the producer. There were no measurements through which purchase price, selling price, and profit could be compared with grade of lambs. The lambs used were above average in grade and, in general, the purchase and selling prices were above average. No estimates could be made, however, to determine if the gain in selling price compensated for the extra costs. It seems probable that the major portion of the premium paid for superior feeder lambs would have to come from an increase in selling price as the low correlation between feeder grade and gain tends to indicate that the better grades of lambs gain little, if any, more economically than the poorer ones when all are healthy.

Summary

1. The correlations and regressions between initial weight, feeder grade, total gain, finished grade, B.A.E. carcass grade, and packer carcass grade were measured on several thousand lambs. All these statistics were computed on an intra-lot basis.

2. With all lambs marketed at one time, initial weight, feeder grade, finished grade, and B.A.E. carcass grade showed considerable relationship, the correlation coefficients varying from 0.35 to 0.54. Packer carcass grades were only slightly related with any of these other measurements.

3. Marketing the lambs as they finished resulted in decreasing the number of very light and overweight carcasses and, in general, reduced slightly the advantage of greater initial weight and superior feeder grade.

4. The use of more than one of the measures studied in estimating gain, finished grade, and carcass grade of lambs did not appear practical although slightly more accurate estimates of each were secured.

5. The average rating of lambs increased approximately one grade during fattening. In general, "Good" feeder lambs graded "Choice" when finished and dressed out "Choice" carcasses.

6. Standardization and acceptance of lamb carcass grades on the basis of

value and the use of such standard in the daily purchase of live animals seems desirable. An investigation should also be made of the relationship between profit and grade in lambs as it applies to the breeder, feeder, and packer.

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SOME ASPECTS OF FERTILITY IN HORSES RAISED UNDER WESTERN RANGE CONDITIONS

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United States Department of Agriculture[2]

DURING the 15-year period, 1926–1940, a considerable number of horses were raised at the U. S. Range Livestock Experiment Station, Miles City, Montana, with the primary purpose of developing improved types of saddle and work stock for use on the western range.

Throughout the study somewhat extensive data were obtained on rate of growth and development, occurrence and duration of estrual periods, gestation, artificial insemination, fecundity and fertility levels, mortality rates, and disease. This paper reports some of the aspects of reproduction in the experimental stud, particularly: (1) the number and sex ratio of foals obtained, and (2) the effects of age and breed of mare, stallion used, and year of breeding on fertility levels.

Material

The mares used were classified into four groups: 11 purebred Belgians; 44 purebred Morgans; 66 grade draft; and 88 grade light mares. They varied in age from 2 to 19 years, except that for some of the grade mares the age was unknown.

Fourteen stallions were used during the different stages of the work, i.e., 2 Belgians, 2 Nonius, 4 Morgans, 5 Thoroughbreds, and one grade Standardbred.

Care of Breeding Stock and Breeding Procedures

The general plan followed for management of the mare stock consisted of extensive utilization of range pastures as the primary source of feed and annual matings for all sound, healthy individuals when 3 years old or older. Foals produced by these mares usually ran with their dams on pasture until weaning time, when they were separated and placed on supplemental feed (grain and hay) until one year old. From the yearling stage to maturity, range pastures furnished the bulk of the ration for both fillies and colts and no other feed was utilized except during work periods or when adverse climatic or health conditions necessitated it.

Usually, the stallions received grain and roughage daily and were kept

[1] Bureau of Animal Industry, Washington, D. C. The authors acknowledge assistance of J. R. Quesenberry, superintendent of The U. S. Range Livestock Experiment Station, and E. B. Osborn, who was directly responsible for collection of the data.

[2] This work was conducted cooperatively by the Bureau of Animal Industry and the Montana Agricultural Experiment Station.

stabled at station headquarters, the mares being brought to them for breeding. In some instances, however, sires used on Morgan and grade light mares were turned on pasture with the females. Generally in these cases each stallion was kept with his band of mares about 40 days, or what normally would be two estrual periods. During the 1926–1936 interval, natural service was practiced almost exclusively, but artificial insemination was used with many of the mares in 1937, 1938, and 1939, when Andrews and McKenzie (1941) were studying estrus, ovulation, and related phenomena in the mares. During all years some of the mares were bred in only one estrus period; others were mated in two, three, or four periods. Sometimes there was only one service in a period; in others there were several. Naturally there was no record kept of the number of services for those mares bred on pasture, but it has been assumed that they were served at least once during each heat period.

The mares were bred in April, May, June, and July, with most of the matings being made in June so that the colts would be foaled the following May approximately at the beginning of the pasture season.

Results

Considering each mare as a different unit for the separate years, 953 matings were made throughout this study. Of these, 567 resulted in the production of 568 foals, including one set of twins. Under usual methods of calculation, this gives the stud a general fertility level of 59.6 percent, a figure considerably higher than that obtained under average practices but lower than might be expected in specialized production. Utilizing another method of calculation, i.e., a comparison of the number of foals resulting from the matings made in all estrual periods in which the mares were served, which totalled 1214, the stud's fertility level for the 15-year period was 46.8 per cent.

Under either method of analysis, the fertility level differed from year to year more than should be expected by chance as determined by the χ^2 test. When measured by the percent of foals to the number of mares bred, the level of fertility ranged from 43.5 percent in 1927 to 73.7 percent in 1937. There was, however, no definite trend (table 1). A similar result was obtained, except that the percentages were lower, when fertility was measured by the number of foals dropped compared to the number of estrus periods in which the mares were bred. In 1927 and in 1933 the level of fertility was particularly low. A number of things may have operated to cause this, such as the use of stallions with low fertility or unfavorable weather and range conditions. Two of the three stallions used in 1927, and two of the three used in 1933 had lower than average records of fertility. Unfortunately, the

TABLE 1. FERTILITY BY YEARS, BY NUMBER OF MARES BRED, AND NUMBER OF ESTRUS PERIODS

Years	By mares		By estrus periods	
	No. of mares	Percent foals	No. of periods	Percent foals
1926	59	67.8	87	46.0
1927	69	43.5	96	31.3
1928	61	67.2	75	54.7
1929	70	68.6	85	56.5
1930	73	61.6	82	54.9
1931	84	58.3	130	37.7
1932	76	61.8	95	49.5
1933	81	44.4	124	29.0
1934	70	57.1	101	39.6
1935	54	51.9	67	41.8
1936	62	54.8	73	46.6
1937	57	73.7	62	67.7
1938	66	63.6	66	63.6
1939	71	64.8	71	64.8
Total	953	59.6	1,214	46.8

records contain but little detailed information on weather and feed conditions and nothing that would indicate their probable effects in these two years. In 1937, 1938, and 1939 the work of Andrews and McKenzie (1941) undoubtedly accounted for a part of the increase in fertility, because, under their direction, an intensive program was inaugurated for teasing the mares and determining optimum times for mating.

Significant differences were found between the average fertility for mares of the various breeds, when the number of foals dropped was compared with the number of mares bred (table 2). When the total number of all foals born was compared to the number of estrus periods, fertility averages for

TABLE 2. FERTILITY BY BREED, BY MARES, AND BY ESTRUS PERIODS

Breed of mare	Average age when bred	By mares		By estrus periods	
		No. of mares bred	Percent foals	No. of periods	Percent foals
Belgian	6.7	44	70.5	51	60.8
Grade-draft	7.4	328	50.0	402	39.1
Morgan	7.1	180	72.2	234	55.6
Grade-light	7.6	401	60.6	527	46.1
Total	7.4	953	59.6	1,214	46.8

all mares of the different breeds were not significantly different. However, using only those mares which were bred in at least four estrus periods gave averages which were statistically different. Here again the differences may be partly due to the stallions used rather than to the breed of the mares, but there is some evidence of a real variation in fertility between the grade-draft mares and the purebred Belgians. Thus it was found that the Belgian stallion,

TABLE 3. FERTILITY BY AGE, BY MARES, AND BY ESTRUS PERIODS

Age of mare	By mares		By estrus periods	
	No. of mares bred	Percent foals	No. of estrus periods	Percent foals
2	4	25.0	4	25.0
3	99	56.6	124	45.2
4	125	57.6	165	43.6
5	105	58.1	141	43.3
6	96	60.4	129	45.0
7	94	70.2	118	55.9
8	78	65.4	88	58.0
9	67	67.2	77	58.4
10	56	69.6	66	59.1
11	47	57.4	57	47.4
12	40	50.0	61	32.8
13	29	58.6	37	45.9
14	24	50.0	32	37.5
15	18	61.1	23	47.8
16	12	41.7	15	33.3
17	7	0.0	11	0.0
18	2	0.0	4	0.0
19	2	50.0	3	33.3
Unknown	48	54.1	59	44.1
Total	953	59.6	1,214	46.8

"Rowdy," sired a significantly higher percentage of foals, 73.9, when mated with the Belgian mares than with grade-draft mares, 47.2. It is possible, of course, that this difference was due in part to the management of the mares or some other factor rather than that of breed, but there is no evidence to prove it. When the Belgian sire, "Purdue's Plato," was bred to grade-draft mares and to Belgian mares, the difference (15.9 percent) was also in favor of the Belgian mares, but it was not statistically significant.

The age of the mares when bred was found to affect fertility, particularly when all the females were studied as a group (table 3 and figure 1). From these data it is seen that there is a tendency for fertility to increase gradually from three to seven years of age and then to gradually decline.

From this material it will be noted also that the fertility of the grade-draft mares does not follow the general trend but tends to be low in the period from six to 12 years of age. This does not seem normal, but the cause is not apparent.

When the effect of the stallions on fertility was studied by comparing sires which were mated in the same manner to eight or more of the same mares, though of necessity at different times, it was found that in 7 out of 15 cases the differences in fertility were significant (table 4).

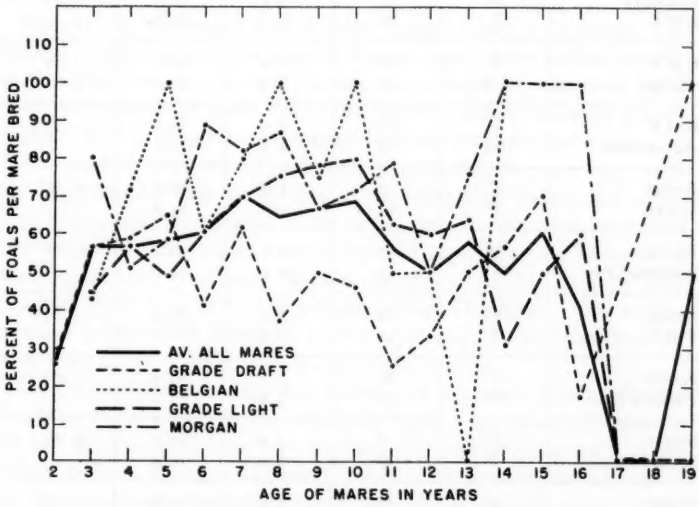

Figure 1. The relation of age of mare to fertility.

A number of the stallions were not at the station during the same period, which limited the comparisons it was possible to make. Many of the mares were kept for quite a few years and were bred to one stallion when young and to another when older. This introduced the factor of variation due to age. The average ages of the mares used with the stallions compared were, however, within the period of greatest fertility.

There were only eight abortions reported. All these were in the grade-draft and grade-light mares. The aborting mares varied in age from 4 to 14 years. Probably there were other abortions which would have been reported, if the mares had been handled under different circumstances.

While not dealing directly with fertility, the percent of foals raised to

TABLE 4. COMPARISON OF THE FERTILITY OF STALLIONS BRED TO THE SAME MARES

Stallions compared	Breed of stallions[1]	No. of estrus periods	Av. age of mares	Percent foals	P[2]
Monterey	M	79	9.7	60.8	.93
Revere	M	57	6.3	59.6	
Monterey	M	17	8.3	41.2	.15
Southern Cross	T	41	7.1	22.0	
Monterey	M	94	9.4	60.6	.95
K of K	T	80	6.1	61.2	
K of K	T	25	10.4	56.0	.34
Albion	GS	15	8.7	40.0	
K of K	T	26	7.2	59.0	.93
Admiration	M	10	9.5	61.5	
Jupiter	T	9	5.4	77.8	<.01
Sunfast	T	24	5.8	25.0	
Revere	M	13	7.2	92.3	<.01
Southern Cross	T	25	10.9	24.0	
Revere	M	62	7.3	56.4	.81
K of K	T	50	6.9	60.0	
Rowdy	B	81	7.1	49.4	.79
Purdue's Plato	B	47	7.4	53.2	
Shorty	N	8	9.4	87.5	<.01
Southern Cross	T	46	5.5	10.9	
Shorty	N	18	6.7	50.0	.04
Sunfast	T	18	6.9	83.3	
Shorty	N	11	8.9	45.4	.08
Purdue's Plato	B	11	9.6	81.8	
Southern Cross	T	96	6.0	17.7	<.01
Sunfast	T	50	8.5	66.0	
Southern Cross	T	73	10.7	20.6	<.01
K of K	T	54	7.2	51.8	
Purdue's Plato	B	31	5.0	64.5	.02
Longfellow	N	20	5.5	30.0	

[1] B = Belgian, T = Thoroughbred, N = Nonius, M = Morgan, GS = Grade Standardbred.

[2] A probability (P) value of .05 or less was considered significant, one of .01 or less as highly significant.

weaning age (about 6 months) under range conditions is of interest. Of the 525 foals on which records were kept to weaning age, 458 or 87.2 percent were weaned. Of the 67 which died, 15 were either born dead or died at foaling time, 4 died of accidents, 10 were destroyed, 5 were not mothered, 11 died of illness, and 22 were listed as missing or dead of unknown causes.

Discussion

The fertility level of all the mares included in this 15-year study, 59.6 percent, is a little above but quite close to the average reported by most investigators.

Kern (1938), Hammond (1921), Lowe (1938), Lambert, Speelman, and Phillips (1939), Harper (1921), and Robinson (1921) report foaling percentages ranging from 42.3 to 72.0 percent, the averages in some cases being based on thousands of mares. While the numbers used in this study are not as great, they are large for experimental work and for individual studs.

The work of Andrews and McKenzie (1941) during the years 1937, 1938 and 1939 indicates that the fertility of the Miles City Station stud might have been improved somewhat in the earlier years if more careful attention had been given to mating the mares at the most opportune time. However, it would apparently be difficult to raise the general fertility level of large groups of mares much above a 65 percent average. This figure is close to that obtained by the U. S. Remount Service (1941-42-43) in its Northwestern Area work (1939, 61.2%; 1940, 60.3%; 1941, 65.0%).

Careful consideration of the data obtained in this study clearly indicates that some of the sires were not sufficiently fertile and undoubtedly some of the low fertility could have been eliminated by prompt replacement of the poorer stallions. This is evidenced by a tabulation omitting the matings of the Thoroughbred, "Southern Cross," with the grade-light mares, which raised the fertility level for this group from 43.3 to 56.1 percent.

The effect of the age of the mare on fertility was similar to the results given by Lambert, Speelman, and Phillips (1939) for the United States Morgan Horse Farm, except that they found the highest fertility in mares from 11 to 14 years of age.

Although a variation in fertility was found to be associated with the breed of mares, it seems likely that this difference is primarily a matter of more careful selection of the breeding stock and of more proper management of the mares particularly at breeding time, rather than of inherent differences between breeds. The fact that a group of grade-draft mares, which is the class having the lowest fertility in the study, produced 63.2 percent foals when mated by artificial insemination supports this view.

The sex ratio of 97.6 males per 100 females is quite close to that reported

by Crew (1927), who found the secondary sex ratio in the horse to be 98.3 males to 100 females. It is, however, somewhat lower than that found by Lambert, Speelman, and Phillips (1939) of 108.4 males per 100 females at the U. S. Morgan Horse Farm. Palmer (1942) reports that for the years 1922–1939 inclusive, of 67,044 Thoroughbred foals registered in England, 50.56 percent were males, while of 80,296 in the United States (disregarding late registrations) there were 50.78 percent females. This is 101.1 and 98.4 males per 100 females, respectively.

Because of the nature of these data, particularly because fertility is an alternative or categorical variate so far as its expression for a single mare in a given season is concerned and because of lack of numbers in the subclasses (when all the different groups are studied separately), it has not been feasible to separate entirely the effects of the various characters on fertility.

Summary

Data are presented on certain aspects of fertility of 209 mares bred to 14 stallions over a 15-year period at the U. S. Range Livestock Experiment Station, Miles City, Montana, in a cooperative study with the Montana Agricultural Experiment Station.

The general fertility level was 59.6 percent (based on the number of mares bred) and 46.8 percent (based on the number of estrus periods in which the mares were bred).

The effect of year was apparently not connected with any trend but there were indications that it was associated with the fertility of the particular stallions used in different years.

Very young mares as well as old mares appeared to have a lower fertility than mares of intermediate ages.

The order of fertility of the mares of the different breed groups was Belgian, Morgan, grade-light and grade-draft. Differences in the stallions used and possibly management appeared to account for much of the difference.

Significant differences were found between the fertility of stallions bred to the same mares in seven out of 15 comparisons.

One set of twins was obtained in 567 foalings.

The sex ratio was 97.6 males per 100 females for all the foals (568).

Eighty-seven and two-tenths percent of the foals born were weaned. The numbers dying of different causes are listed.

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THE EFFICIENCY OF THE PHENOTHIAZINE SALT MIXTURE AND DRENCH FOR SHEEP[1]

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PARASITES are the greatest threat to the health of sheep and their economic use of feedstuffs.

The introduction of phenothiazine as an anthelmintic for sheep parasites by Harwood, Habermann and Jerstad (1939) and Habermann and Harwood (1940), has led to many investigations on the use of this drug. Shorb, Habermann and Heemstra (1941), compared phenothiazine to the combination copper sulphate, nicotine sulphate drench with the result that phenothiazine was more effective for the removal of helminths from the gastrointestinal tract. During the summer of 1942, we compared phenothiazine to the common anthelmintics used for sheep, Thorp and Keith (1943). The results of this study indicated that phenothiazine was a more effective anthelmintic when compared to other treatments. The 1–9 phenothiazine salt mixture was used on a group of Merino ewes and lambs with such encouraging results that this method of administration was suggested. Research workers of the Bureau of Animal Industry, United States Department of Agriculture, experimented with the same mixture and on the basis of their findings, recommended the 1–9 phenothiazine salt mixture as a satisfactory anthelmintic and labor saving procedure. Britton, *et al.* (1942) claimed beneficial results in the control of parasitism in lambs by the use of a 1–15 phenothiazine and salt lick. These investigations and others indicated that the use of a mixture of phenothiazine and salt had possibilities as a method of treatment for sheep parasites. The efficiency of the phenothiazine drench has been well established.

Materials and Methods

The sheep used in these studies were selected as follows; Twenty Merino ewes from last year's experimental flock; ten ewes of the common mutton breeds; fifty spring lambs consisting of forty Southdown and Shropshire, and 10 Merinos. The Merino lambs were picked from the group of lambs

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produced by the 20 Merino ewes maintained on the 1–9 phenothiazine and salt mixture.

Fecal examinations were made each week during the summer months, using the method described by Shorb, *et al.* (1941), which had proved very satisfactory the previous season. White blood cell counts, red blood cell counts, and hemoglobin determinations were made upon sixty of the experimental sheep at two-week intervals. The Haden-Hauser hemoglobinometer was used for the hemoglobin determinations.

Experimental Data

The experimental sheep were divided into five groups. Group I consisted of the twenty Merino ewes, which had been on the 1–9 phenothiazine and salt mixture since the beginning of these studies in June 1942, and ten of their twenty-three lambs. White blood cell counts, red blood cell counts and hemoglobin determinations were made at biweekly intervals on all the sheep in this group. The average weekly parasite egg counts for these sheep are shown in figure 1 (1 and 2). All the sheep in this group, including the lambs, will be continued on the 1–9 phenothiazine and salt mixture indefinitely. This is to determine if any toxic manifestations develop when the sheep are started on the 1–9 mixture as lambs. Group II consisted of ten mutton ewes of three breeds and their 10 lambs, in which case the ewes had been drenched in the fall and spring after lambing. These lambs did not receive any treatment for the entire summer, but the ewes and lambs were placed on a pasture lot which had not been used for sheep since the previous fall. The parasite egg counts for the group are shown in figure 1, (3 and 4). Group III consisted of ten spring lambs which were drenched with the 12½ gram dose of phenothiazine at the beginning of the experimental period. During the remainder of the period they were given the 1–9 phenothiazine and salt mixture at two-week intervals for a period of one week. The parasite egg counts for this group are shown in figure 1 (5). Group IV consisted of ten spring lambs, which were given a 1–14 phenothiazine and salt mixture continuously for the twenty-week experimental period. They did not receive any other treatment. The average weekly parasite egg counts for the group are shown in figure 1 (6). Group V consisted of 10 lambs which did not receive any type of treatment and were used as the untreated controls for the experimental period. Two of these lambs died of parasitism between the tenth and twelfth weeks of the experiment. The average weekly egg counts for group V are shown in figure 1, chart 7.

The parasite egg counts for all the groups are shown in terms of the total count and the count for Haemonchus contortus. With the exception of the parasite egg counts shown for ewes in the experiment, the egg counts for

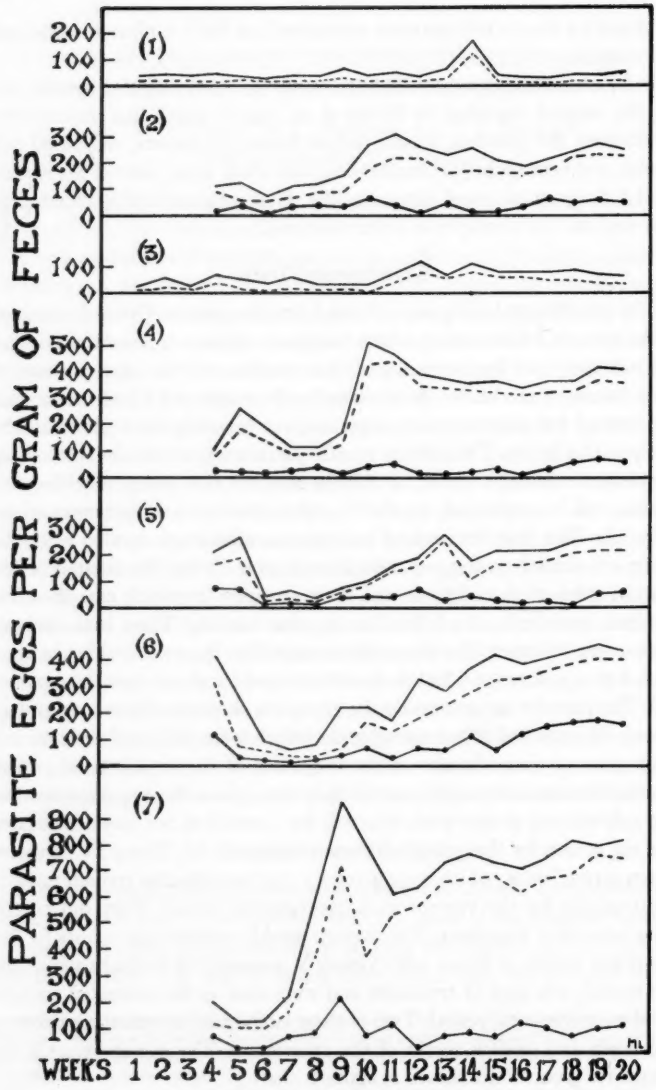

Fig. 1. See next page for legend.

species other than Haemonchus were averaged and that average shown on the charts.

Weekly parasite egg counts were made of the following species of nematodes; Strongyloides, Trichostronglylus, Cooperia, Ostertagia, Haemonchus, Oesophagostomum, Nematodirus and Bunastomum. Space does not permit the showing of the average weekly parasite egg count for all species of nematodes other than Haemonchus, although the others were considerably lower and showed the same general fluctuations. The presence of parasite eggs other than the species mentioned above was not observed or they were present in insignificant numbers. Tapeworm eggs were observed from time to time in the various groups, but no attempt was made to count these eggs.

White blood cell counts, red blood cell counts, and hemoglobin determinations were made upon all the sheep in groups I, III, IV, and V at biweekly intervals during the experiment. The results for these counts in group I and V are shown in figure 2 (8 and 9). The results of this study in groups III and IV did not show any abnormalities.

Discussion

This investigation has been a follow-up of the previous year's study, at which time the 1–9 phenothiazine salt mixture was suggested. The early work of Harwood (1939), Habermann (1940) and others showing that phenothiazine is a nontoxic efficient anthelmintic has been confirmed a number of times. It is considered by many to be one of the best anthelmintics for sheep.

Reports of toxic manifestations and anemia produced or aggravated by the administration of phenothiazine were of immediate concern with the introduction of the 1–9 salt mixture. These reports, for the most part, followed the use of phenothiazine with horses and swine. All chemicals and drugs used as anthelmintics for parasitic infestations in animals are somewhat injurious. Phenothiazine is one of the least toxic of the anthelmintics

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Figure 1. The average weekly egg counts on:
(1) 20 ewes given 1–9 phenothiazine and salt for 19 months.
(2) 10 lambs given 1–9 phenothiazine and salt.
(3) 10 ewes drenched with phenothiazine, fall and spring.
(4) 10 lambs, not treated but with the treated ewes.
(5) 10 lambs drenched and given 1–9 phenothiazine and salt at two week intervals for one week.
(6) 10 lambs given 1–14 phenothiazine and salt mixture continuously.
(7) 10 lambs which received no treatment.
——— Total count.
- - - - - Haemonchus contortus count.
●—●—● Average of other species.

for sheep. Therefore, the 20 Merino ewes of group I were maintained on the 1–9 phenothiazine and salt mixture for the past 19 months for the purpose of making certain blood studies as well as the weekly parasite egg counts during the summer season. The results of the blood studies on this group are

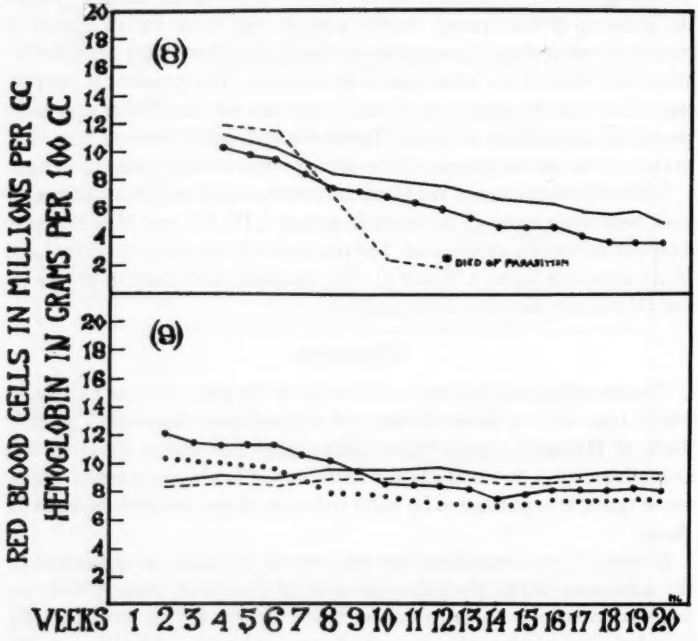
RED BLOOD CELLS IN MILLIONS PER CC
HEMOGLOBIN IN GRAMS PER 100 CC
(8)
(9)
DIED OF PARASITISM
WEEKS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Figure 2. The average biweekly red blood cell count and hemoglobin for:
(8) 10 lambs which received no treatment, ———— Gms. of hemoglobin; ●—●—● millions of red blood cells per cu. mm.; - - - - - hemoglobin of one lamb which died of parasitism.
(9) Ewes and lambs on continuous dosage of 1–9 phenothiazine and salt.
———— Gms. of hemoglobin for ewes.
- - - - - Millions of red blood cells per cu. mm. for ewes.
●—●—● Gms. of hemoglobin for lambs.
● ● ● ● ● Millions of red blood cells per cu. mm. for lambs.

shown in figure 2, chart 9. The fact that there was no change in the red blood cell counts and the hemoglobin of the blood for the twenty ewes after nineteen months of continuous administration of the 1–9 mixture shows that no anemia was produced. This would indicate that no toxicity was produced by the continuous treatment. The slight drop in red blood

cell counts and hemoglobin content of the blood for the lambs is not significant.

Autopsies of three of the Merino ewes which had been on the 1–9 phenothiazine and salt mixture for nineteen months did not show any gross pathology. A histopathological study of sections from the liver, kidney, and spleen did not show any marked tissue changes. Further microscopic studies will have to be made on tissue sections from the remaining animals on the experiment before a complete report on any pathological changes can be made.

A study of figure 1 (1) shows that the average parasite egg count with the exception of the fourteenth week was below 100 eggs, including all species. The only noticeable factor found upon a study of the egg counts was that some of the ewes had a sudden increase in the number of nematode eggs. However, the rise is not abnormally high and since it dropped during the next two weeks and has remained low, it is not regarded as of particular importance.

The average weekly parasite egg counts for the lambs are considerably higher than that for the ewes. None of these lambs showed gross evidence of parasitism but some were carrying a mild infestation of parasites as indicated by the egg counts. This difference in the egg counts would suggest that young lambs do not consume enough of the 1–9 salt mixture to prevent the development of a mild infestation. One contributing factor in the case of these lambs was the fact that they were late lambs and well into the parasite season before they were of sufficient size to consume enough of the salt mixture.

The average weekly parasite egg count [figure 1 (3)] for the ten mutton ewes in group II, drenched fall and spring, did not show any marked increase in infestation. These ewes and the ten lambs of this group were on a pasture not used for sheep since the previous fall. The ten lambs received no treatment during the experimental period. The parasite egg count for the lambs in this group [figure 1 (4)] indicated that the residual infestation in the ewes may be enough to develop an infestation in the lambs if they receive no treatment. None of these lambs died from parasitism but a number showed gross evidence of infestation.

A comparison of the average weekly parasite egg counts for groups III and IV [figure 1 (5 and 6)] indicated that the procedures used for these groups under the conditions of the experiment were not as satisfactory as the others. Gross evidence of parasitism was observed in several lambs in each group; however, no marked changes were observed upon a biweekly study of the blood.

The average weekly counts for group V, the untreated control group, are shown in figure 1 (7). These lambs were on the same pasture lots as groups

III and IV. All the lambs in this group ended the experimental period in very poor condition and with severe symptoms of parasitism as indicated by the red blood cell counts and hemoglobin determinations shown in figure 2 (8).

A comparison of the efficiency of the phenothiazine salt mixture in various forms and the difference in its effectiveness as a preventive measure in ewes and lambs is indicated by a study of the total counts for all the various forms of treatment.

Summary and Conclusions

Although there is more to be learned about the efficient use of phenothiazine, on the basis of this and other work, it is thought that definite recommendations can be made at this time. The use of phenothiazine, either as a salt mixture or as a drench, may be modified for various localities, depending upon climatic conditions and the general management practices.

The 1–9 phenothiazine and salt mixture, prepared by mixing 1 pound of phenothiazine powder with 9 pounds of granular salt, if properly administered, is an efficient non-toxic anthelmintic for mature sheep. The difference in efficiency for lambs and ewes is probably due to the fact that the young lamb does not consume enough of the salt mixture when needed most and the further fact that the lamb is more susceptable than the ewe to parasitism.

The use of phenothiazine and salt is a preventive measure and is not expected to control parasitism in heavily infested animals.

The following general recommendations are made:

1. Treat all the sheep in the flock during the late fall or early winter with the phenothiazine drench.

2. Repeat this treatment in the spring one to two weeks after all the ewes have lambed. Then, place the entire flock on the 1–9 phenothiazine and salt mixture.

3. Drench the lambs in the flock with phenothiazine when they are 3 to 4 months of age. If it is a wet, warm season and the lambs show any evidence of parasitism, it may be necessary in some cases to drench them again.

4. Under some conditions, particularly after using the fall and spring drench for several seasons, it may not be necessary to drench the ewes in the fall if they were drenched in the spring, providing the 1–9 salt mixture has been before them at all times. All the young stock kept over the winter should be drenched in the fall.

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AN ATTEMPT TO IMPROVE A CONCENTRATE MIXTURE COMPOSED OF YELLOW CORN, BEEF MEAL, SOYBEAN MEAL AND ALFALFA MEAL FOR WEANLING PIGS IN DRYLOT[1]

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Introduction

In STUDIES on the protein requirements of growing-fattening pigs at the Illinois Station, several abnormal conditions have developed in the pigs fed in the drylot experiments. In these earlier tests with 30-pound weanling pigs, the gains were very unsatisfactory; and many pigs had to be removed from the experiment. Some pigs died, and only a few made satisfactory gains. A ration of ground yellow corn, beef meal, soybean meal, alfalfa meal, and salt was fed at various protein levels. Some of the abnormalities were: emaciation, diarrhea, anorexia, weakness, mild dermatitis, and failure to grow. Post mortem examination of the pigs did not reveal any pathological organisms. When some of the most severely affected pigs were self-fed liver meal in addition to the 26 percent total protein ration, the growth rate and the condition of the pigs improved to a marked degree.

Since the improvement occurred on a high protein ration supplemented with liver meal, the abnormal conditions in the pigs could not be attributed to feeding excessive amounts of protein (Robison, 1940). Certainly an inadequate supply of protein or a deficiency of an essential amino acid would not be suspected since the ration was composed of corn, beef meal, soybean meal, alfalfa meal and salt and contained 26 percent total protein. The study reported in this paper was an attempt to find a concentrate mixture which would bring about satisfactory growth in pigs fed in drylot from weaning to 75 pounds in weight. This period of growth is probably the most critical and has been the least explored of any period in the growth of pigs.

Keith, *et al.* (1942) and Wright (1939–40) have fed rations similar to the basal mixture used in these Illinois tests, and their experiments indicate that the response of pigs is not entirely satisfactory. Their feed mixtures were composed of corn and trio mixture, or some slight modification of this combination of feeds. Other workers have found that many feed mixtures made

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up of commonly-used ingredients are often inadequate for pigs fed in drylot.

When Ellis and Madsen (1941) fed dry skimmilk, they found it of considerable value in preventing incoordination in growing swine. On the other hand, Eveleth and Biester (1937) found that dry skimmilk was not a potent source of the factor which prevents "paralysis" in pigs. Wright (1939–40) reported that the addition of dry skimmilk to a ration of corn and trio mixture did not improve the rate or economy of gains for pigs from weaning to market, while Robison (1938) found that the addition of dry skimmilk to a feed mixture of yellow corn, tankage, linseed meal, ground alfalfa hay, salt mixture and cod-liver oil increased the rate of gains and decreased the feed required for 100 pounds of gain for pigs fed from 40 to 115 pounds in weight. However, in the Ohio trials the dry skimmilk did not improve the concentrate mixture for the pigs from 115 pounds to market weights. In these and other studies, the results from feeding dry skimmilk in addition to other protein supplements have not always been in agreement.

Oats have given excellent results in swine rations when used in moderate amounts. The studies of Carroll, *et al.* (1937) showed that ground oats may be fed as one-fourth to one-third of the ration without decreasing (appreciably) the rate of gain. These experiments with 60-pound pigs also showed that hulled oats increased the rate of gain when fed with corn, tankage and alfalfa meal, but hulling the oats was less profitable than grinding. Robison (1928, 1931) and others have also reported that in drylot rations, hulled oats increased the rate of gain and decreased the amount of feed required per 100 pounds of gain. This was also true in the pasture trials of Weaver (1937). Wright (1939–40) found that pigs gained more rapidly when 25 percent of the corn was replaced with ground oats than when corn was fed alone with the trio mixture. Recently Spector and Elvehjem (1942) reported that oats is a good source of pantothenic acid, nicotinic acid, and a fair source of pyridoxine. It is also known that oats is among our best cereal sources of thiamin. Perhaps the content of B vitamins in oats has been a contributing factor in bringing oats into such great favor as a livestock feed. In studies on necrotic enteritis Davis, Freeman, and Madsen (1940) found that oats was one of the best sources of nicotinic acid among our cereal grains.

Studies, in which dried corn distillers' solubles has been used to fortify practical rations for growing pigs in drylot, have been reported by Fairbanks, Krider and Carroll (1944) and Krider, Fairbanks and Carroll (1942, 1944). In these experiments the addition of small amounts of dried corn distillers' solubles to basal rations, which did not include alfalfa meal, resulted in more rapid gains.

In the experiments reported in this paper, all supplementary feeds, namely, hulled oats, dry skimmilk and dried corn distillers' solubles were

added to a basal feed mixture which contained five percent of average quality alfalfa meal.

Experimental Procedure

In the two tests, 148 weanling pigs in eight lots were fed the concentrate mixtures given in table I. The animals used in the 1941 spring test were obtained from litters that were fed in creep feeding experiments on rye pasture, while the pigs used in the 1941 fall test were raised on clean pasture and

TABLE 1. COMPOSITION OF CONCENTRATE MIXTURES FED

Lot number	1 Basal ration	2 Basal plus hulled oats	3 Basal plus dry skimmilk	4 Basal plus dried corn distillers' solubles
Feeds	*pounds*	*pounds*	*pounds*	*pounds*
Ground yellow corn	61.8	33.3	60.1	58.7
Beef meal (66%)	21.8	18.6	20.8	20.8
Soybean meal	10.9	9.3	10.4	10.4
Alfalfa meal	5.0	5.0	5.0	5.0
Hulled oats	—	33.3	—	—
Dried skimmilk	—	—	3.2	—
Dried corn distillers' solubles	—	—	—	4.6
Salt	0.5	0.5	0.5	0.5
Total	100.0	100.0	100.0	100.0
Average chemical analyses:				
Dry matter, percent	87.82	89.30	88.57	88.28
Ether extract, percent	5.72	6.14	5.32	5.46
Crude protein, percent	24.25	23.97	24.62	24.59
Ash, percent	4.40	3.96	4.71	4.81
Crude fiber, percent	3.81	3.48	3.56	3.55
Nitrogen-free extract, percent	49.64	51.75	50.36	49.87

were not subjected to any experimental treatment prior to the initiation of the test.

Each pig started on test at weaning time (56 days) and continued on the experiment until it weighed approximately 75 pounds. The average initial weight per pig was about 30 pounds. Throughout the test, weekly individual live weights were taken, and each pig weighed off the experiment at the weigh day when its weight most closely approximated 75 pounds. All lots of pigs were self-fed in the central barn on concrete floors with concrete runways.

The mixtures were formulated, on the basis of the total protein contents

of the ingredients used to contain approximately 25 percent crude protein. The chemical analyses of the samples of the mixtures which were obtained by sampling the mixtures as they were fed showed that the total protein content varied from 23.6 to 24.8 percent of crude protein. The average chemical analyses of the rations fed are given in table I.

The basal group (lot 1) was fed a mixture of ground yellow corn, beef meal, soybean meal, alfalfa meal and salt. Lot 2 received the basal mixture with 50 percent of the corn replaced with hulled oats. Lot 3 was fed the basal ration plus 3.2 percent of dry skimmilk, while lot 4 received the basal mixture plus 4.6 percent of dried corn distillers' solubles, which is known to be a source of many water-soluble vitamins.

Results and Discussion

The essential data which summarize the two experiments are presented in table 2. The average daily gains for the two tests were 0.83, 0.96, 0.84 and 0.83 pounds for the lots of pigs fed the basal ration and the basal ration supplemented with either hulled oats, dry skimmilk, or dried corn distillers' solubles, respectively. The average feed eaten for 100 pounds of gain for the two tests are by lots, respectively, 308, 286, 324 and 322 pounds.

In both tests, the pigs in lot 2 which were fed hulled oats made more rapid daily gains and consumed less feed to produce 100 pounds of gain than the other lots. With the analysis of variance as described by Snedecor (1938) for groups with unequal numbers, the differences in average daily gains between lot 2 and lot 1, between lot 2 and lot 3, and between lot 2 and lot 4 were highly significant statistically.[4] However, analysis of variance did not show any significant[4] differences in daily gains of lots 1, 3, and 4 which could be ascribed to the rations.

A serious disadvantage of the group-feeding ad libitum technique is apparent in this experiment. The pigs of lot 2 gained significantly faster than those of the other lots, but it is difficult, if not impossible, to explain definitely the observed differences.

The pigs of lot 2 consumed on the average 0.075 pounds more feed per head per day than those in lot 3 which is the lot with a daily feed consumption most closely approximating that of lot 2. The calculated gross energy intake of lots 2 and 3 was 5014 and 4761 large calories respectively. Assuming that 60 percent of the gross energy is metabolizable and that 60 percent of the latter is net, then each pig in lot 2 consumed 91 large calories more of net energy daily for maintenance and gain in weight than the pigs of lot 3. Since the average daily gain of the pigs in lot 2 was 0.12 pound more than in

[4] $P = 0.05$, significant. $P = 0.01$, highly significant.

lot 3, these pigs would have required for the additional gain at least 134.6 large calories (Mitchell and Hamilton, 1929)[8] more of net energy per day, but only 91 additional large calories were estimated to be available. Consequently all of the additional gain could not be accounted for on the basis of

TABLE 2. THE ADDITION OF EITHER HULLED OATS, DRY SKIMMILK, OR DRIED CORN DISTILLERS' SOLUBLES TO A BASAL RATION OF GROUND YELLOW CORN, BEEF MEAL, SOYBEAN MEAL, ALFALFA MEAL AND SALT FOR GROWING-FATTENING PIGS FROM WEANING TO 75 POUNDS

Lot number	1	2	3	4
Treatment	Basal	Basal plus hulled oats	Basal plus dry skimmilk	Basal plus dried corn distillers' solubles
First trial, 1941 spring—all pigs self-fed in drylot				
No. of pigs started	20	20	20	20
No. of pigs finished	20	20	20	19
Av. initial weight, pounds	32	32	32	32
Av. final weight, pounds	75	75	75	75
Av. daily gain, pounds*	0.94	1.00	0.94	0.98
Ave. daily feed per pig, pounds	2.52	2.68	2.73	2.74
Feed eaten for 100 lbs. gain, lbs.	273	264	293	282
Second trial, 1941 fall—all pigs self-fed in drylot				
No. of pigs started	17	17	17	17
No. of pigs finished	17	14	14	15
Av. initial weight, pounds	28	29	28	28
Av. final weight, pounds	76	78	76	76
Av. daily gains, lbs.*	0.70	0.88	0.69	0.64
Av. daily feed per pig, pounds	2.23	2.58	2.38	2.24
Feed eaten for 100 lbs. gain, lbs.	343	309	354	363

* For the pigs that finished.

energy intake, especially when it is considered that all of the net energy is not available for gain in weight, since the increased maintenance requirement of the heavier pig must be met first. Therefore, part of the additional gain obtained in lot 2 may be explained by the nutritional qualities of the hulled oats.

When the results of lot 2 and lot 1 are studied in a similar manner, most,

[8] These workers reported that one gram of gain in swine of this weight contains 2.47 large calories.

if not all, of the difference in gains may be explained on the basis of greater caloric intake. Such an observation may suggest that all differences observed in this experiment may be explained on the basis of caloric intake. Such a possibility is frankly admitted, but the method used to estimate net energy is not absolute, and the nutritional concept that feed intake may be associated with nutritional adequacy cannot be ignored. To explain such a nebulous thing as palatability entirely by nutritional adequacy is further than the authors care to go, but they do believe that nutritonal adequacy of a ration and feed intake are associated to some extent.

The pigs of lot 4 were fed dried corn distillers' solubles in addition to the basal ration, and were receiving adequate amounts of the B vitamins known to be necessary for the pig, if published requirements may be accepted (Fairbanks, Krider and Carroll, 1944). There may be some question concerning the availability of vitamins in natural ingredients, but this problem has not been studied extensively with the pig. Present information supports the statement that thiamin, riboflavin, nicotinic acid, pantothenic acid, pyridoxine and probably choline were supplied in adequate amounts to the pigs in lot 4. If the response of 30-pound weanling pigs to the feeding of hulled oats was not entirely due to greater caloric intake, then it may have been due to (1) the increased supply of known factors, thus indicating a larger requirement for pigs of this weight, or to (2) the addition of an unidentified nutritional factor(s) found in the hulled oats. Further experiments are necessary in order to determine which of the above possibilities is correct.

Summary

Two experiments in which 148 head of 30-pound weanling pigs were fed to a final weight of seventy-five pounds are reported. A basal concentrate mixture of ground yellow corn, beef meal, soybean meal, alfalfa meal, and salt was compared with the basal ration plus either hulled oats, dry skimmilk or dried corn distillers' solubles. The data indicate that hulled oats contributed to the nutritive qualities of the basal mixture. The mixture which contained hulled oats produced significantly more rapid daily gains and also more economical gains than the basal mixture, or the basal mixture plus dry skimmilk or dried corn distillers' solubles. The addition of the amount of dry skimmilk and dried corn distillers' solubles fed in these tests, did not improve the nutritive properties of the basal concentrate mixture used for weanling pigs.

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HEREDITARY AND ENVIRONMENTAL FACTORS AFFECTING GROWTH RATE IN SWINE[1]

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SELECTION is one of the important tools the animal breeder has at his disposal for livestock improvement. However, its effectiveness depends on the heritability of the selected character, i.e. the extent to which variation in these characters is transmitted from parent to offspring. Theoretical aspects, methods of estimation, and the practical significance of heritability have been discussed by Lush (1940).

Several workers have investigated the inheritance of growth rate in swine. Lush (1936) reported a heritability estimate of 24 percent for rate of gain in bacon hogs from data obtained from the Danish swine-testing stations. Berge (1936) in a report on pig-testing in Norway found that 13 percent of the total variance for rate of gain in the Yorkshire breed, and 5 percent in the Landrace breed could be accounted for by differences between boars used in the herds. Whatley (1942) concluded from his study of 180-day weight in Poland China pigs that between 30 and 40 percent of the variance was of genetic origin. Whatley and Nelson (1942) estimated the heritability of 180-day weight in Duroc swine as 23 percent. Bywaters (1937) concluded that about 18 percent of the variance in weaning weight of Poland Chinas was genetic. However, only about a quarter of this 18 percent was additively genetic. Comstock, *et al.* (1942) estimated the influence of heredity on weaning weight, 180-day weight, and post-weaning growth rate in several inbred lines of pigs. They believe the real value of the heritability of weaning weight is low possibly as a result of sub-optimum nutrition of the suckling pigs. They further pointed out that since 180-day weight includes weaning weight, it is probably subject to greater environmental variation than are measures of post-weaning growth rate. Hetzer (1942) reported paternal half-sib correlations for pigs at several different ages. The correlation was lowest at weaning and highest at 140 days of age.

Smith and Donald (1939) divided the post-weaning growth period, arbitrarily, into three intervals of 28 days each. Their data indicate that heredi-

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tary differences for growth are more clearly expressed after than before weaning.

Baker, *et al.* (1943) determined the heritabilities of several intervals of growth from birth to 168 days as well as weights at several ages. They concluded that the influence of heredity on growth increases in importance up to about 112 days of age and thereafter decreases.

Hazel, *et al.* (1943) determined the heritability of three 56-day periods of gain from birth to 168 days and the correlations between these periods. They found that gain in the period from 56 to 112 days measured hereditary growth rate for 168 days as accurately as actual gain from birth to 168 days.

This study was undertaken to investigate further the heritability of the growth curve in swine with a view to finding the most useful measure of hereditary growth.

Source and Description of Data

The data for this investigation were obtained from swine raised by the Minnesota Agricultural Experiment Station in cooperation with the U. S. Regional Swine Breeding Laboratory. This study is based on the records of 2,396 pigs representing 340 spring litters farrowed at four sub-stations over a five-year period. The data include weights at specific ages from birth to 168 days and gains in the intervals between these ages, as well as the average rates of gain per day calculated both from birth to 200 pounds and from weaning to 200 pounds. Seven inbred lines are represented in these data. The average inbreeding calculated by Wright's formula is about 21 percent. All pigs were weaned at 56 days and averaged 33.7 pounds. After weaning all litters were raised in separate lots. The average rate of gain per day from weaning to 200 pounds is 1.53 pounds. The regression for rate of gain from weaning to 200 pounds on percent of inbreeding computed within years and lines is $-.0022 \pm .0010$. This coefficient indicates the expected amount of decline in growth rate when inbreeding is practiced without selection.

Figure 1 illustrates the mean growth of these pigs along with the corresponding 20th and 40th percentiles above and below the mean. (These are corrected for station and year differences.) The general nature of the skewness peculiar to growing pigs is revealed. Certain animals that fail to gain well, either because of disease or poor genotype for growth, are responsible for the "fanning out" of the distributions toward the lighter pigs. This graph also illustrates the increase in variation about the average curve as the pigs increase in age and weight.

In table 1 the intra-litter standard deviations are given in percent of the mean for weights at different ages. These coefficients of variation indicate that factors causing variation within litters are relatively more important

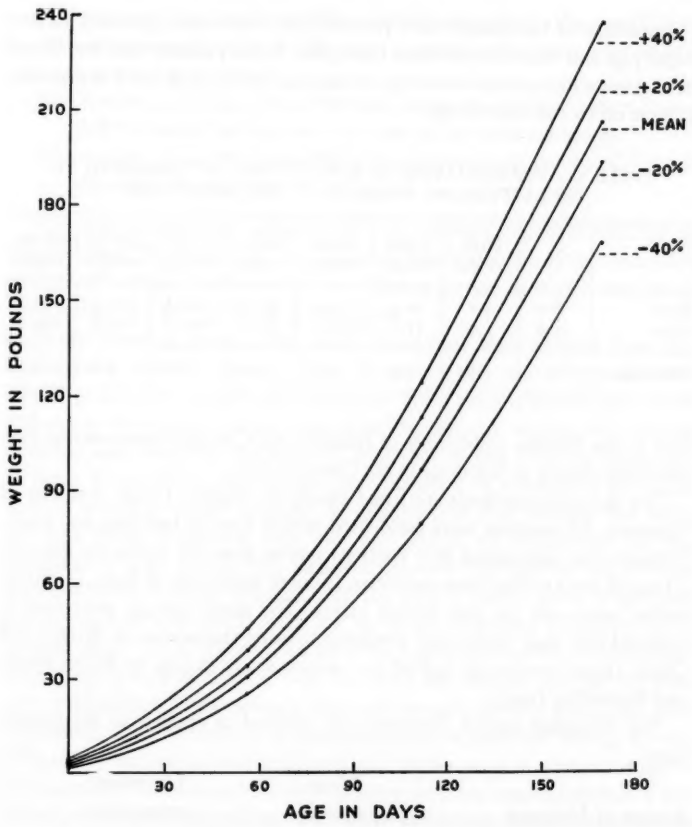

Figure 1. Mean growth curve for 2,396 pigs with the 20th and 40th percentiles above and below the mean.

TABLE 1. THE INTRA-LITTER COEFFICIENTS OF VARIATION FOR WEIGHTS AT DIFFERENT AGES

Age	Birth weight	21-day weight	56-day weight	84-day weight	112-day weight	140-day weight	168-day weight
C.V.	14.7	15.0	16.4	15.0	12.6	11.6	10.8

during the period immediately preceding and following weaning than at any other time.

Inspection of the present data revealed that older sows generally farrow larger pigs and wean heavier ones than gilts. Table 2 shows that sow litters have about a four-pound advantage at weaning which they tend to maintain at least up to 168 days of age.

TABLE 2. AVERAGE GAINS OF SOW-LITTERS AS COMPARED TO GILT-LITTERS BY WEIGHTS AT DIFFERENT AGES

	N	Birth weight	21-day weight	56-day weight	84-day weight	112-day weight	140-day weight	168-day weight
Sows	860	3.1	12.9	36.4	65.8	107.8	154.9	209.1
Gilts	1536	2.9	11.4	32.2	61.6	103.0	150.7	204.8
Differences		.20	1.5	4.2	4.2	4.8	4.2	4.3

Part 1. The Relative Importance of Heredity and Certain Environmental Factors Contributing to Variance in the Growth Curve

The statistical methods are based chiefly on Fisher's (1938) Analysis of Variance. All analyses were conducted within lines of breeding and years. Variance was segregated into portions arising from the following sources: (1) age of dams within lines and years, (2) sires within age of dams, (3) litters within sires, and (4) pigs within litters. The mean squares were further analyzed into their theoretical components using the method of Winsor and Clarke (1940) previously applied to a similar study in pigs by Baker, Hazel, and Reinmiller (1943).

The following outline illustrates the method as applied to the present case:

Sources of Variance	*d/f*	*Mean squares*	*Theoretical composition*
Age groups within lines and years	$p-q=22$	Y	$A+(m/n)B+(m/o)C+(m/p)D$
Sires within age groups	$o-p=64$	X	$A+(m/n)B+(m/o)C$
Litters within sires	$n-o=230$	W	$A+(m/n)B$
Pigs within litters	$m-n=2056$	V	A

Where:

m = total number of pigs = 2396
n = total number of litters = 340
o = total number of sire groups = 110
p = total number of age groups of dams = 46
q = total number of line-year groups = 24

A = variance resulting from differences between pigs in the same litters.
B = variance resulting from differences between contemporary litters having a sire in common.
C = variance resulting from differences between groups of litters having different sires but farrowed by dams of the same age group.
D = variance resulting from differences between age groups of dams in the same line and year.

The assumption of the method is that the different sources of variance are independent. The letters A, B, C, and D which symbolize the theoretical amount of variance attributed to the different factors as shown may be approximated by solving the equations given.

In the breeding system from which these data were derived there was considerable selective mating. That is, some of the sire groups were farrowed principally by gilts and others by older sows. Accordingly, if sire differences were taken without regard to this selective mating, the variance between sires would be confounded with that arising from age differences of dams. Bywaters (1937) reported that the effect of increase in age of the sow on weaning weight is relatively unimportant after the sow has had a previous litter. Therefore, only two age groups are considered: (a) pigs farrowed by gilts, and (b) pigs farrowed by sows that had had one or more previous litters. In cases where a boar was bred to both a group of gilts and a group of older sows in the same line, he would contribute 2 degrees of freedom for sires.[3] Thus, there are a total of 64 degrees of freedom between sires within age groups of dams $(o-p)$ but there are actually only 46 between sires within lines. Since variance coming from each sow and gilt group is independent, these 64 degrees of freedom should be valid for testing the significance of variations among sire groups.[4] However, it is recognized that a more accurate estimate of the true genetic variance existing within a line would have been obtained had each degree of freedom resulted from the use of a different sire.

From Fisher (1918) and Wright (1921) it can be shown that the total additively genetic variance in a line may be apportioned as follows:

Between sires in a line (non-sib groups) $= \frac{1}{4}$
Between litters within sires (half-sib groups) $= \frac{1}{4}$
Between pigs within litters (full-sib groups) $= \frac{1}{2}$

[3] By this procedure, the mean square "sires within age groups," which is used for testing "age groups within line and season" is made somewhat larger than it should be. However, this was not found to be of much importance since it enters the picture only when the mean square for sires is larger than its appropriate error; in respect to post-weaning gains, in all cases where this occurs, the age effects are small.

[4] Subdivision of progeny from a sire into a sow and gilt group, while increasing degrees of freedom, would also cause a corresponding decrease in number of pigs per sire group. Therefore, the F value for testing sire differences would decrease accordingly and should offset the increase in degrees of freedom

Assuming that sire groups are subject to the same environmental factors of variation, the non-random variance among them would be solely genetic. Between half-sib litters, in addition to the genetic variance present, certain environmental factors, particularly the amount of milk produced by each dam, would contribute to the observed variance. Within litters the variance would be made up not only of additive and non-additive genetic variance, but also of intangible factors of environment that act on each pig uniquely.

From the procedure suggested by Dickerson (1942) and Baker, *et al.* (1943) the mean square components may be further analyzed. Expressing these components as fractions of the total, the relative amounts of genetic and environmental variance contained in each may be calculated. Since these data are based on lines that average 20 percent inbreeding, the within-line genetic variance should be 20 percent less than that found in the foundation herd. The following illustrates these relationships:

Variance lost through inbreeding

$$I/T = .2\,H$$

Variance remaining within the inbred line

$$A/T = .4\,H + P$$
$$B/T = .2\,H + L$$
$$C/T = .2\,H$$
$$D/T = \quad + F$$

Variance corrected to a non-inbred population

$$1 = H + P + L + F$$

Where:

A, B, C and D = components of variance associated with individual pigs, litters, sires, and age groups, respectively.

I = reduction of genetic variance within the lines due to inbreeding.

T = total absolute variance = $A+B+C+D+I$

H = fraction of variance that is genetic and combines additively in a randomly bred population (heritability).

P = fraction of variance resulting from environmental effects, dominance deviations, and gene interactions peculiar to individual pigs.

L = fraction of variance resulting from environmental effects peculiar to each litter as a whole.

F = fraction of variance resulting from differences between age groups of dams.

Since $.2\,H$ equals the fraction of genetic variance lost through inbreeding, $1-.2\,H$ would be the total fraction of variance remaining in the line after 20 percent inbreeding. Then $H+P+L+F=1$ represents the variance corrected to a non-inbred population.

In all analyses which follow, the main interest lies in estimating *H*, *P*, *L* and *F*. Since *H* represents the proportion of additively genetic variance found in a random-bred population its estimation has considerable practical bearing on the problem of selection. The relative importance of the environ-

TABLE 3. INTRA-LINE AND YEAR ANALYSES OF VARIANCE FOR WEIGHTS AT DIFFERENT AGES

Source of Variance		Birth weight	21-day weight	56-day weight	84-day weight	112-day weight	140-day weight	168-day weight
Mean Squares								
Age of dams	(*Y*)	2.2**	93.0**	926.7**	1649.9**	2177.1**	3096.7**	4222.1
Sires	(*X*)	0.9	16.3	132.6	355.1	796.1	1429.0*	2484.7*
Litters	(*W*)	1.0**	22.0**	181.8**	437.9**	795.4**	987.9**	1591.2**
Pigs	(*V*)	.2	3.2	30.4	89.8	175.3	312.6	500.7
Mean Square Components								
Age of dam effects	(*D*)	.025	1.4	14.3	23.3	26.5	32.0	33.4
Sire effects	(*C*)	—	—	—	—	.0	20.3	41.0
Litter effects	(*B*)	.108	2.7	21.5	49.4	87.9	95.8	154.7
Individual litter effects	(*A*)	.190	3.2	30.4	89.8	175.3	312.6	500.7
Variance (absolute)								
Age of dam effects	($\frac{1}{4}F=D$)	.025	1.4	14.3	23.3	26.5	32.0	33.4
Genetic	($\frac{1}{4}H=\frac{1}{2}C$)	—	—	—	—	.2	101.3	205.1
Litter environment	($\frac{1}{4}L=B-C$)	.108	2.7	21.5	49.4	87.9	75.5	113.7
Individual pig environment	($\frac{1}{4}P=A-2C$)	.190	3.2	30.4	89.8	175.3	272.1	418.6
Total	($\frac{1}{4}T$)	.323	7.3	66.2	162.5	289.9	480.9	770.8
Percent of Variance								
Age of dam effects	(*F*)	7.6	18.8	21.6	14.3	9.2	6.7	4.3
Genetic	(*H*)	—	—	—	—	.1	21.1	26.6
Litter environment	(*L*)	33.5	36.7	32.4	30.4	30.3	15.7	14.8
Individual pig environment	(*P*)	58.9	44.5	46.0	55.3	60.4	56.5	54.3
Total		100.–	100.–	100.–	100.–	100.–	100.–	100.–

* $P<.05$. ** $P<.01$.

mental variances *P*, *L* and *F* have practical application provided a knowledge of these may allow greater standardization of certain environmental factors that contribute to observed variance. Any reduction in environmental variance would permit hereditary differences to show up more clearly.

Table 3 contains the complete analysis for weights at different ages. The

mean squares for the age effect of dams is highly significant through 140 days. Its relative importance is shown by (F) which attains a maximum of 21.6 percent at weaning and decreases gradually thereafter to 4.3 percent at 168 days. No estimate of genetic variance was obtainable in the first four ages

TABLE 4. INTRA-LINE AND YEAR ANALYSIS OF VARIANCE FOR DIFFERENT PERIODS OF GAIN

Source of Variance		21–56 day gain	56–84 day gain	84–112 day gain	112–140 day gain	140–168 day gain
Mean Squares						
Age of dams	(Y)	629.9**	184.3	314.2	466.6	293.3
Sires	(X)	104.1	166.5	228.9*	286.1*	320.0**
Litters	(W)	114.9**	128.4**	157.5**	179.7**	215.1**
Pigs	(V)	20.4	31.9	38.5	57.3	67.8
Mean Square Components						
Age of dam effects	(D)	9.9	.3	1.6	3.5	—
Sire effects	(C)	—	1.8	3.3	4.9	4.8
Litter effects	(B)	13.4	13.7	16.9	17.4	20.9
Individual litter mate effects	(A)	20.4	31.9	38.5	57.3	67.8
Variance (absolute)						
Age of dam effects	($TF=D$)	9.9	.3	1.6	3.5	—
Genetic	($TH=5C$)	—	8.8	16.4	24.4	24.1
Litter environment	($TL=B-C$)	13.4	12.0	13.6	12.5	16.1
Individual pig environment	($TP=A-2C$)	20.4	28.4	32.0	47.5	58.2
Total	(T)	43.7	49.5	63.6	87.9	98.4
Percent of Variance						
Age of dam effects	(F)	22.6	.7	2.6	4.0	—
Genetic	(H)	—	17.7	25.8	27.8	24.5
Litter environment	(L)	30.7	24.2	21.4	14.2	16.4
Individual pig environment	(P)	46.7	57.4	50.2	54.0	59.1

* $P<.05$. ** $P<.01$.

since the mean squares for sires (X) were smaller than the appropriate error mean squares (W). In only the last two weight periods are sire mean squares significant. The genetic variances (H) for weights at 140 and 168 days are about 21 and 27 percent, respectively. All litter mean squares are highly significant. The environmental portion common to litter mates (L) reaches

TABLE 5. INTRA-LINE AND YEAR ANALYSES OF VARIANCE OF GAINS 56 AND 112 DAYS AFTER WEANING AND FOR RATES OF GAIN FROM BIRTH TO 200 POUNDS (R_1) AND WEANING TO 200 POUNDS (R_2)

Source of Variance		56 days	112 days	R_1	R_2
Mean Squares					
Age of dams	(Y)	645.4	2,527.8	.06984*	.13235
Sires	(X)	541.2*	2,181.2**	.03635*	.10625**
Litters	(W)	358.5**	1,030.4**	.02508**	.05404**
Pigs	(V)	93.4	378.1	.00795	.01974
Mean Square Components					
Age of dam effects	(D)	2.0	6.7	.00064	.00050
Sire effects	(C)	8.4	52.8	.00052	.00240
Litter effects	(B)	37.6	92.5	.00243	.00487
Individual litter mate effects	(A)	93.4	378.1	.00795	.01974
Variance (absolute)					
Age of dam effects	(TF = D)	2.0	6.7	.00064	.00050
Genetic	(TH = 5C)	42.0	264.2	.00259	.01199
Litter environment	(TL = B − C)	29.2	39.7	.00191	.00247
Individual pig environment	(TP = A − 2C)	76.6	272.5	.00692	.01495
Total	(T)	149.8	583.1	.01206	.02991
Percent of Variance					
Age of dam effects	(F)	1.3	1.1	5.3	1.7
Genetic	(H)	28.1	45.3	21.4	40.1
Litter environment	(L)	19.5	6.8	15.9	8.2
Individual pig environment	(P)	51.1	46.8	57.4	50.0

* P < .05. ** P < .01.

36.7 percent at 21 days and steadily decreases to about 15 percent at 168 days. The residual variance (*P*) peculiar to individual pigs does not appear to follow any particular trend but roughly accounts for about half of the variance at any given age.

The analysis for different periods of gain is given in table 4. It will be noted that the age effect of dams is significant only within the period of gain from 21–56 days. At this time (*F*) accounts for 22.6 percent of the total variance. In the following period, 56–84-day gain, it has fallen to .7 of 1 percent. Apparently, the age of dam effect on gains after weaning is negligible. However, its effect on weight after weaning was shown in the preceding

analysis to be lost only gradually. The mean squares for sires are significant in the last three periods of gain. The genetic variance (*H*) in each of these periods seems to account for about a quarter of the total. Litter environment (*L*) shows a regular tendency to decrease in importance from 30.7 per-

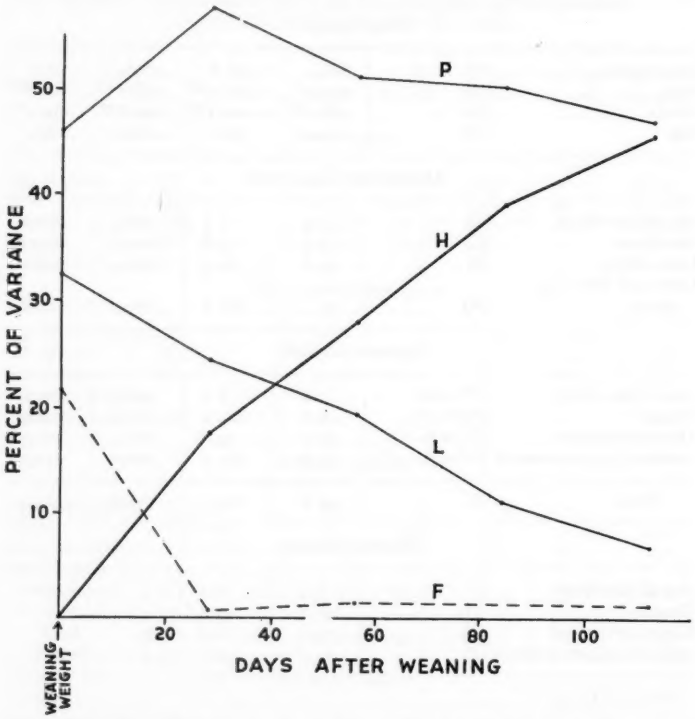

Figure 2. The relative importance of heredity and environmental factors on aggregate gains after weaning.
H=Heredity
P=Environment peculiar to individual pigs
L=Environment common to litters
F=Environment common to pigs farrowed by dams of the same age group

cent in the first period to 16.4 percent in the last. The residual pig variance (*P*) again appears to account for half of the variance, more or less, in all periods.

Since selection for growth rate based on a 28-day period of gain would

be subject to considerable error in weighing, periods of longer duration should be used as a criterion for selection. It, therefore, was considered worthwhile to compare the heritabilities of the aggregate gains at the end of each 28-day period following weaning.

The analyses for weaning weight, and gains 28, 56 and 112 days post-weaning, contained in tables 4 and 5, are summarized in figure 2.[5]

Environment peculiar to individual pigs (*P*) is evidently the greatest source of variance and fails to show any definite trend, whereas effects common to each litter (*L*) appear to decrease in a linear order from 32 percent at weaning to 7 percent 112 days after weaning. This decrease in *L* presumably allows genetic differences to expose themselves more definitely in the longer periods.

TABLE 6. HERITABILITY ESTIMATES BASED ON OFFSPRING-DAM REGRESSION[1] (WITHIN SIRE GROUPS) FOR DIFFERENT PERIODS OF GAIN AND FOR RATES OF GAIN FROM BIRTH TO 200 POUNDS (R_1) AND WEANING TO 200 POUNDS (R_2)

	Birth wt.	21-day wt.	21–56 day gain	56–84 day gain	84–112 day gain	112–140 day gain	140–168 day gain	R_1	R_2
Regression coefficient (b)	+.07	−.03	−.01	+.03	+.05	+.05	+.05	+.02	+.11
Standard error of b	.05	.07	.06	.05	.05	.05	.06	.07	.06
Heritability (2b)	14.			6.	10.	10.	10.	.03	.21

[1] The average of litters and the corresponding values for dams constitute the offspring-dam pairs.

Table 5 also contains analyses on the daily rates of gain from birth to 200 pounds (R_1) and weaning to 200 pounds (R_2). The validity of these measures, frequently used as indices for growth, is based on the fact that pigs are more generally fed to a standard weight than to a standard age before marketing. From a producer's standpoint, therefore, these measures might be considered of more practical importance than others. The heritability (R_1) is estimated at about 21 percent as contrasted to a heritability of 40 percent for (R_2). These are in fair agreement with the estimates of 27 and 45 percent calculated for 168-day weight and gains from weaning to 168 days, which strongly indicate the effect of pre-weaning environmental variation on the hereditary nature of total gains. However, the fact that these estimates appear too widely divergent will be discussed later.

[5] To complete the picture, but at the same time to save labor in calculations, the variance for 84-day gains after weaning was approximated by calculating, directly, the mean squares for sires and litters, and assuming that F is negligible and P is 50 percent of the total variance, which seems reasonable from a study of tables 3 and 4. In this manner L and H were estimated as 11 and 39 percent, respectively.

Part 2. Offspring-Dam Regressions

In the present data there were 312 pairs of dams and their litters that could be used to calculate intra-sire and line regressions of offspring on dam. As a further restriction, however, the regressions were calculated between litters born in the same year and season, and out of dams born in the same year and season. Thus, the estimates of heritability are based on the proportion of the genetic variance to the total variance appearing among pigs in a line within seasons of farrow and born out of sows farrowed in the same season. This method of estimating heritability is discussed by Lush (1940).

In table 6 are found the regression coefficients and corresponding heritability estimates for birth weight, 21-day weight, gains from 21 to 56 days, and gains in the four 28-day post-weaning periods. Although these regression coefficients are small and not statistically significant, the trend for the heritability of the growth curve as indicated by these coefficients is in general agreement with the other results reported save for the rather large regression coefficient found for birth weight.

Included also in this table are the offspring-dam regressions for the rates of gain from birth to 200 pounds and weaning to 200 pounds. The heritabilities based on the regressions given are 3 and 21 percent for R_1 and R_2, respectively. These are considerably lower than the estimates previously given from the paternal half-sib correlation analysis and the differences probably represent sampling error.

Discussion

It can be shown from Bywaters (1937) that the two methods used in this investigation estimate slightly different portions of the genetic variance. Four times the paternal half-sib correlation approximates the additively genetic variance plus one-fourth the variance from epistatic deviations, whereas, twice the parent-offspring correlation estimates the additively genetic variance plus one-half that caused by epistatic deviations. This ignores interactions involving more than two gene pairs; if these are numerous the difference in composition of these two estimates of variance should be less than given. Lush (1940) defined only the additive portion of the genetic variance as heritable in the "narrow sense." However, the portion of the variance caused by epistatic deviations that contributes to the heritability as estimated from dam-offspring regression is heritable as well in the sense of the transmissibility of a character.

The results of this study which are based on paternal half-sib correlations afford direct comparison with one already reported from the Nebraska Station by Baker, Hazel, and Reinmiller (1943). They concluded that "the

interval of growth immediately preceding 112 days appears to offer the greatest opportunity for the identification of animals possessing the heredity for rapid growth rate." In contrast, this study indicates that maximum benefit could be derived by measuring gains from weaning to at least 168 days of age. Weight at 112 days of age was found to be the most highly heritable weight in the Nebraska study, as opposed to an estimate of essentially zero found in this work. Moreover, reasonably large estimates of heritability were found for ages under 112 days in the former study while no estimates were obtainable in the latter. With respect to 140 and 168-day weights, however, the two studies are in essential agreement. As concerns the heritability of gains by periods, the greatest discrepancy is found for the period from 112 to 140 days. The Nebraska study yielded an estimate of four percent while this study found an estimate of 28 percent.

The fact that these two studies show certain points of disagreement is not surprising. The differences reported might be accounted for in several ways. The obvious and most reasonable procedure would be to explain the differences as due to sampling errors. It is known that these estimates are subject to large errors which make it probable that none of the differences are significant statistically. However, no satisfactory method has been devised for calculating the standard error of the heritability statistic as obtained from paternal half-sib correlations.

There are other factors that might explain these differences. First, variance arising from differences in age of dams was found to be an important source of variance during the pre-weaning period in this study. This may or may not have been a significant source of variance in the Nebraska study. If the females bred to some of their boars were predominately gilts while those bred to others were predominately sows this could have contributed significantly to the variance referred to as genetic and would result in an overestimation of the heritability of their pre-weaning gains. In this study when sire differences were taken within lines and without regard to ages of dams the "heritability" for gains from 21 to 56 days was calculated as 29 percent which strongly suggests a bias introduced by this factor. Second, the Nebraska study was based on line differences while this study was based on differences within lines. If any differentiation in lines through inbreeding with respect to milking capacity of the sows took place, this would tend to cause differences in pre-weaning gains. These differences might be interpreted as hereditary growth differences when in reality they are hereditary differences in milking capacity. Third, since these studies were based on two different populations of pigs, both inbred, and under different environments, one might suspect not only differences in the relative amounts of genetic variance present in each herd, but also differences in the relative

influence of environmental factors acting on gains over the entire period of growth.

The results of this investigation indicate that weaning weight has little value as an index of hereditary growth impulse, but is a useful index of a sow's milking capacity.

It appears that selection based on the entire interval from weaning to 168 days will result in greater hereditary gains for growth rate than any portion of this interval. The results, do suggest however, that selections up to 140 days of age yield almost as much progress as up to 168 days. The saving in time and labor in a large breeding project by basing selections on gains to 140 days might balance the differences found in heritability of gains taken at greater ages.

That weight for age will not be as effective as post-weaning gains follows logically since all post-weaning weights include pre-weaning gains. Therefore, the extent to which extra-genetic factors, such as the amount of milk produced by the sow and size of litter, cause variations in weight, will be reflected in post-weaning weights. Based on the results of half-sib correlations, 168-day weight was found to be 27 percent heritable; while that of gains from 56 to 168 days was about 45 percent. Likewise, the heritability of the average daily rate of gain from birth to 200 pounds was estimated at 21 percent while that for gains from weaning to 200 pounds was found to be about 40 per cent (from half-sib correlation).

There appears little doubt, however, that the differences reported between estimates of heritability containing and not containing pre-weaning growth are over-estimated. This is because the estimates of genetic variance obtained for pre-weaning growth were negative while the true genetic variance cannot be less than zero. Furthermore, estimates of genetic correlation between genotypes before and after weaning were found to be negative while the true correlation probably should be positive. In spite of these facts, it is not believed that the estimates as reported should be altered. If they err too far in one direction they will be counteracted by other estimates reported erring in the opposite direction.

The results as reported furnish evidence that heritability of post-weaning gains is greater than of post-weaning weights. Even though the estimates appear too widely divergent it would be easier to explain this as sampling error deviations from a true difference than as sampling error deviations from equality.

This study indicates that there is a little advantage in measuring growth rate to a standard age as compared to a standard weight. However, the hereditary growth of most interest to the commercial hog producer is that

up to market weight since it is customary to market pigs at a standard weight rather than a standard age. Moreover, pigs that are kept on a growing-fattening ration to a standard age may become excessively fat which might hinder their subsequent breeding performance. This could be prevented by changing rations when the animals reach a standard weight. On the other hand, if performance was recorded only to 140 days of age, there should be little tendency for pigs to become overly fat since only a few will have reached market weight at that age. Selecting for growth rate on gains from weaning to 140 days of age would perhaps be applicable only to herds averaging about the same rate of gain as the animals on which this study was made.

Summary

Analyses of variance and offspring-dam regression techniques were used to analyze data on 2,396 pigs and 312 dam-litter pairs, respectively, in order to investigate factors of heredity and environment affecting the growth curve of swine. The data included weights and gains in intervals from birth to 168 days, as well as average daily rates of gain from birth to 200 pounds (R_1) and weaning to 200 pounds (R_2).

Pigs farrowed from sows were about four pounds heavier at weaning than pigs from gilts. This advantage was maintained at least to 168 days of age.

The variance arising from age differences of dams accounted for 22 percent of the total intra-line and year variance in weaning weight. These age differences appeared to have no influence on gains after weaning while their influence on weight after weaning declined only gradually.

Environmental variance common to each litter was greatest at 21 days and accounted for 37 percent of the total variance. On gains after weaning it decreased from 24 percent, 28 days post-weaning, to 7 percent, 112 days post-weaning.

Environmental effects peculiar to individual pigs accounted for approximately one-half of the total variance in the periods of gain and weights studied.

The heritabilities of gains 28, 56, 84, and 112 days post-weaning were estimated as 18, 28, 39, and 45 percent, respectively, from analyses of variance. Those for R_1 and R_2 were estimated as 21 and 40 percent, respectively. The heritability of R_1 and R_2 as estimated from regression of offspring on dam was 3 and 21 percent, respectively.

It is concluded that the differences reported between estimates of heritability containing and not containing pre-weaning growth are over-estimated. However, the results furnish evidence that heritability of post-weaning gains is greater than of post-weaning weights.

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EFFECTS OF AN UNFRACTIONATED PITUITARY EXTRACT UPON CYSTIC OVARIES AND NYMPHOMANIA IN COWS[1]

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NYMPHOMANIA as it is manifested in cows has been described by various authors: Zschokke (1900), Albrechtsen (1917), Hess (1921), Quinlan (1929), Williams (1939). Although the descriptions vary somewhat with regard to the appearance of the animals and the changes in their behavior, there is agreement that the conditions which they have described are associated with the presence of cystic follicles and absence of luteal tissue in the ovaries. Quinlan (1929) in addition, pointed out that a number of cows, affected with cystic degeneration of the follicles, show anaphrodisia.

It would appear that the morphological and behavioral changes which accompany cystic ovaries are quite variable. Sexual interest may be entirely absent or there may be irregular or prolonged estrual periods. The cow may be unwilling to accept the male but at the same time she may assume such masculine behavior as pawing, bellowing, and riding of other cows. The conformation of the animal may be normal or there may be changes to that resembling a bull. In such cases there is relaxation and sinking of the sacrosciatic ligaments, elevation and coarsening of the tail-head, hollowing-out of the back and even coarsening of the head and neck. The external genital organs usually become large and flabby. There may be a vaginal discharge and it may contain more or less flocculent material. Vaginal prolapse may be observed. These several variations are largely ones of degree and in part they appear to be due to the advancement of the pathological condition.

Albrechtsen (1917) in particular, maintained that the formation of cysts is brought about and maintained by disease of the uterus. Quinlan (1929) stated that there appears to be little doubt that the pathological change in the ovaries is a sequel to endometritis, as a result of extension of infection from the uterus through the fallopian tubes to the ovary. Another point of view on the relationship between the uterine and ovarian pathologies might be represented by Hess (1921) who seemed to consider the conditions in the uterus as unassociated, or secondary in character.

Methods of treatment have been based largely on these two points of view. In the first case irrigation of the uterus with a mild antiseptic prepara-

[1] Paper No. 330 from the Department of Genetics, Agricultural Experiment Station, University of Wisconsin. This work was supported in part by a grant from the Wisconsin Alumni Research Foundation.

[2] The cooperators in the field test made in this study have been Mr. T. C. Webster, Mr. Howard Clapp, Dr. Walter Wisnicky, Dr. Herbert Lothe, and Dr. J. T. Schwab. The authors are deeply appreciative of the wholehearted cooperation of these men in the prosecution of the work. Some aid has been given to this study by Project 622-V: Trichomoniasis and other reproductive diseases of cattle. (B. A. Beach, in charge).

[3] Departments of Genetics and Zoology.

ration, combined with repeated manual rupture of the ovarian cysts, would likely be practiced. In the second case, repeated rupture of the cysts would probably be the main procedure, and uterine irrigation would be used only if there was an evident pyometra.

The cystic condition has become corrected in a certain proportion of cows under these treatments. In the main, however, the treatments are not now considered sufficiently effective to warrant the tedious and expensive effort involved unless the animal is of exceptional value.

Following the work of Aschheim and Zondek (1927) and Smith and Engle (1927) who showed the physiological relationship between the anterior pituitary gland and the ovaries, there has been considerable speculation that the gonadotrophins might be utilized in the treatment of cystic follicles. As a matter of fact, however, one of the first attempts to use pituitary gland material in the treatment of such cases antedated the work which has been cited on pituitary gland—ovarian physiology (Pearl and Surface, 1915). Suggestions that cyst-formation may be due to a deficiency in luteinizing hormone or that it might be corrected by injection of gonadotrophic preparations, have been made by Tutt (1932) Gifford (1940) Gould (1941) Perry (1942) and Deubler (1943).

The clinical reports have not given an extensive evaluation of any of the gonadotrophins as to their efficacy in the treatment of cystic ovaries and nymphomania. The present study represents an attempt to determine, systematically, certain of the effects of an unfractionated pituitary extract upon the ovary and sexual behavior when injected into cows with cystic ovaries.

Preliminary Experiments

Preliminary experiments were run on 11 cows with cystic ovaries between October 1934 and May 1938. Only our interpretation of the results of these trials will be given.

Unfractionated extracts of the pituitary gland were used. There was considerable variation in dosage, but the most interesting features arose from the different methods of injection. One cow was given subcutaneous injections only; 7 cows were given a series of subcutaneous injections followed by a single intravenous injection; 1 cow was given an intravenous injection followed by a series of subcutaneous injections; and 2 cows were given only a single intravenous injection. From the subcutaneous injections alone, after 14 days there was an excessive growth of follicles—most of them approximately one inch in diameter. There was no evidence of formation of corpora lutea.

Of the animals that received the series of subcutaneous injections followed by the intravenous injection, all showed evidence of corpora lutea formation

or luteinization of the walls of the cysts. Considerable variation was shown in the amount of luteinization in the different animals and a marked overgrowth of follicles accompanied the luteinization. The latter was construed as undesirable because, in some cases, it persisted until a return of the cystic condition. One cow, however, eventually established a fairly normal estrual cycle, was bred, and conceived.

The condition of the ovaries resulting from the treatment in which the series of subcutaneous injections followed rather than preceded the intravenous injection could not be distinguished from the former treatment, that is, there was some luteinization and an overgrowth of follicles which developed cysts.

Contemporary work with normal cows (Casida, *et al.* 1943) suggested the importance of the intravenous injection in the production of corpora lutea. For this treatment to produce luteal tissue in cystic ovaries it would be assumed that there are follicles large enough to react which are not yet cystic, or that the stratum granulosum of the cysts had not yet degenerated but what it could be converted into luteal tissues, forming a luteinized cyst. There may well be many instances of cystic ovaries where neither of these conditions obtains. Both of the animals treated by the intravenous injection showed the formation of corpora lutea and there did not appear to be the overgrowth of follicles that had been encountered when subcutaneous injections were involved. It is realized that to a certain extent the overgrowth, previously encountered, may have been due to an excessive dosage of the hormones. The simplicity of the treatment by single intravenous injection of the extract made it desirable to determine on larger numbers of animals some of the particular effects of this treatment of cystic ovaries.

Material and Procedure

In addition to the animals which have come under direct observation by the authors since February 1937, the study has been amplified greatly (May 1942 to October 1943) by animals studied through the cooperation of a group of herdsmen and veterinarians. Where treatments were made by the cooperators the hormone preparations were furnished them, together with data sheets calling for detailed descriptions of the behavior and appearance of the animals, and of the condition of the ovaries[4] and genital tracts. A second examination of the animals was to be made, preferably between 10 and 20 days after treatment but in several instances this interval was a month or a little longer. The caretakers of the animals were asked to observe whether

[4] The animals selected for treatment showed by manual examination *per rectum* the presence of one or more follicular cysts, an inch or more in diameter. Palpable corpora lutea or palpable luteal tissue in the walls of the cysts were absent.

the animals quieted in behavior and if possible just when this occurred. They also furnished the records on estrual periods and breeding dates. All pregnancy determinations were made by manual examination *per rectum*, the examinations being made by the persons treating the animals.

The extracts which were used may be classified as unfractionated extracts and were prepared from acetone desiccated sheep pituitary powder (Wilson and Co.). The preparations were made by the methods of McShan and Meyer (1943). Fourteen cows were injected with preparations which corresponded to the "A" fraction described by McShan and Meyer. Eighty-two cows were injected with the "B" fraction. It may be said at the outset that no difference in the physiological response of the cows to these two different extracts was noted.

The gonadotrophic material was recovered from these fractions as a dry powder by precipitating and washing with acetone. The proper amount of this powder was dissolved in 5 cc. distilled water immediately before it was injected intravenously into either jugular vein of the cow. The amount injected was usually one gram-equivalent but actually ranged from 0.67 gram-equivalent to 2.5 gram-equivalents. In the bioassay of these fractions, a dosage of 100 milligram-equivalents produced ovaries weighing on the average approximately 78 mg. when injected twice daily for $4\frac{1}{2}$ days into 21-day old Sprague-Dawley rats, the rats being killed at the beginning of the sixth day.

Results

At the conclusion of the study, the data on the 96 cows were classed into three groups (table 1). All of the animals had cystic ovaries, but some did not show behavioral evidence of nymphomania. Group 1 included cows showing nymphomaniac behavior whose genital tracts as determined by manual palpation *per rectum* did not show marked evidence of endometritis or salpingitis. Group 2 also was composed of nymphomaniac cows (with the exception of two animals) but all showed marked evidence of either endometritis or salpingitis as determined at the clinical examination, or, in a few cases, when the animals came to autopsy. It seems likely that Groups 1 and 2 are not entirely distinct as there probably were some cases of endometritis that had not been recognized in the first group. Group 3 was composed of animals with cystic ovaries, but which did not show nymphomaniac behavior (i.e. they showed anaphrodisia); the genital tracts of these animals appeared to be normal.

The animals in Group 1 (the largest group) were kept under observation for a variable length of time, ranging from 14 to 255 days. Some animals had been treated so recently at the time the data were summarized that information was available only on the ovarian condition after injection and not on

the later breeding behavior. The average length of the observation period following treatment was 110 days.

The duration of nymphomania before treatment was determined from the owners' reports, and ranged from 4 days to 1 year. The average was approximately 64 days, and 38 out of the 71 animals had shown nymphomania for more than 1 month.

Of the 71 animals that were injected in Group 1, 63 of them ceased to

TABLE 1. COWS INJECTED INTRAVENOUSLY WITH AN UNFRACTIONATED PITUITARY EXTRACT

Group	1			2			3
Cows showing:	Nymphomania and normal genital tract			Nymphomania and uterine or tubal pathology			Cystic ovaries but not nymphomania—normal genital tract
Injection	1st	2nd	3rd	1st	2nd	3rd	1st
No. cows receiving the injection	71	12	1	12[1]	4	2	13
Ceased to show nymphomania at least temporarily	63	10	1	9	3	2	—
Ceased to show nymphomania but condition recurred	8	0	1	6	1	1	—
Corpora lutea known to have been formed within 31 days after treatment	55	10	1	10[4]	2	2	9
Showed normal estrus since treatment	52	8	0	7	2	1	10
Showed normal estrus within 31 days after treatment	42[2]	7	0	3	1	1	2[3]
Bred and any breedings checked for pregnancy	46	7	0	6	0	1	7
Total number services checked for pregnancy	71	12	0	17	0	2	9
Pregnant	32	6	0	0	0	0	4

[1] Only 10 showed nymphomania.

[2] Two others had gone only 14 and 22 days respectively after treatment and had not yet shown estrus when the data were summarized.

[3] One other had gone only 4 days after treatment and had not yet shown estrus. A corpus luteum had been formed since injection, however.

[4] Included the 2 cows which did not show nymphomania.

show nymphomaniac behavior, at least temporarily. The caretakers reported when the nymphomania disappeared in 29 of these animals and it varied from 1 to 8 days after treatment. Eight of the 63 animals showed recurrence of the nymphomaniac condition during their observation periods 18 to 160 days after injection. Fifty-five animals were known to have formed corpora lutea within 31 days after treatment (an interval chosen arbitrarily

to cover most of the periods until reexamination of the ovaries). Evidence for this was obtained: (1) by palpation of the ovaries within the 31-day interval; (2) by the occurrence of a normal estrus within the 31 days, which in turn was followed by an examination which showed the presence of corpora lutea; (3) by the occurrence of estrus within 31 days after treatment, which in turn was followed by other estrual periods at fairly normal interestrual intervals. Fifty-two cows showed normal estrual periods (resulting in the formation of corpora lutea) since treatment, and of these, 42 occurred within the 31-day interval. Forty-six of the animals were bred and had at least some breedings checked for pregnancy. These 46 animals had a total of 71 services checked for pregnancy and 32 of the 46 cows were diagnosed as pregnant.

A second injection was given to 12 animals from the group of 16 in which nymphomaniac behavior did not cease, or in which it recurred, and there was a cessation in 10 of the 12 animals after this second injection. None of the 10 showed a recurrence of this condition during the observation period and all 10 were known to have formed corpora lutea within 31 days. Eight of the animals showed normal estrual periods and 7 of these were within 31 days after treatment. Seven of the animals were bred, and had at least some breedings checked for pregnancy. They received a total of 12 services which were checked for pregnancy, and 6 of the 7 animals were pregnant at the end of their observation periods.

One of the 2 animals which did not become quiet after the second injection was given a third. She ceased to show nymphomania and had corpora lutea form within 31 days, but she showed recurrence of the condition 49 days later.

Of the 12 animals which showed some form of uterine or tubal pathology (Group 2; observation period 42 to 398 days), 9 of them ceased nymphomania. This is really 9 out of 10 animals, because 2 of the animals originally did not show nymphomania. In 6 of the 9 animals nymphomania recurred after its original cessation. Corpora lutea were known to have been formed within 31 days in 10 of the 12 animals. Seven showed normal estrual periods after treatment, but in only 3 of these cases did heat occur within 31 days after the treatment. Six of the cows were bred and had some breedings checked for pregnancy. They received a total of 17 services which were checked, but none of the 6 cows were pregnant.

Four of the animals were re-treated either because nymphomania did not cease after the first injection, or because it had returned, and three of these ceased nymphomania. In one of the three, however, there was a recurrence. Two of the animals formed corpora lutea within 31 days. Two showed a normal estrual period, one of which was within 31 days of treatment. None of these animals were bred.

Two animals received a third injection. Both of them ceased nymphomania but one showed a recurrence of the condition. Both of the animals were known to have formed corpora lutea within 31 days but only one showed a normal estrus and that was within 31 days after treatment. She was bred twice, and was checked for pregnancy, but did not become pregnant.

Corpora lutea were formed in 9 of the 13 animals which showed cystic ovaries but not nymphomania (Group 3; observation period 4 to 356 days); the corpora lutea were present within 31 days in all cases. Ten of the animals showed a normal estrus since injection, two of them within 31 days. Seven cows were bred and had some breedings checked for pregnancy. They received a total of 9 breedings, and 4 of the 7 animals became pregnant.

In addition to the data in table 1, the records were also examined with respect to two variables in the treatment of the animals, one having to do with dosage, and the other, with manual rupture of the cysts. Out of the total of 115 injections that were made on the three groups of animals there were 25 instances in which the dosage was 2–2.5 gram-equivalents of the pituitary powder. An examination of the data on these particular dosages showed no discernible difference in the response to the treatment from that observed following the more usual dosage of 1 gram-equivalent.

The other variable in the treatment consisted of rupture of the cysts, either on the day of injection, or 4 days previous to injection. There were 33 instances of this sort out of the 115 treatments and again the results did not appear to differ from the cases in which the cysts were not ruptured. There was a suspicion at one stage of the study that the animals returned into normal estrus within 31 days a little more consistently when the cysts had been broken than when they had not been broken, and that the condition appeared to be asociated with a smaller incidence of luteinized cysts in the ovaries. At the termination of the study, however, no basis for such a conclusion could be definitely established.

Discussion

No difference was apparent in the readiness with which nymphomania disappeared in Groups 1 and 2—those nymphomaniacs that showed normal, as compared with those that showed abnormal genital tracts. The recurrence of nymphomania, however, was greater in those that showed some degree of uterine or tubal pathology (6 out of 9 cases as compared to 8 out of 63 cases, both on first injections).

Formation of corpora lutea within 31 days after treatment appeared to be equally consistent in all three groups. There was consistency, also, in the occurrence of a normal estrus following treatment, but there was more delay in Groups 2 and 3 than there was in Group 1. Groups 1 and 3 appeared to

conceive with about equal readiness but none of the animals which showed uterine or tubal pathology conceived, even though proportionally more breedings were expended on them than on the members of the other two groups.

It was not possible to use any control animals in this study so it is important to question the significance of the findings by whatever means there are at hand. It is believed that some untreated cows may eventually show spontaneous regression of the cysts and the formation of corpora lutea. If reports were available in the literature on the incidence of spontaneous recovery and on the average length of time necessary for it to take place, the above findings could be evaluated by comparison with the reported figures as a check on their significance.

There is another way in which these observations might be questioned: Are the results similar for the different length intervals of nymphomania which the cows showed before injection? Thirty-three animals had shown nymphomania 31 days or less; 12 between 32 and 62 days; 14 between 63 and 93 days; and 12 for 3 to 12 months. The percentages of these animals which showed the formation of corpora lutea within 31 days after treatment were 76, 83, 71 and 83, respectively. This fairly uniform recovery rate of approximately 77% every 31 days would not give support to a concept that the recoveries were spontaneous and coincident with the ending of a characteristic interval for persistence of the ovarian disorder.

If the selection of animals for injection had been completely at random, without regard to the length of time that the animals had shown nymphomania, it might have been possible to obtain an estimate of the spontaneous recovery rate from the distribution of animals showing the condition for different length intervals. It was known, however, that the selection was not entirely at random. Particularly in some herds there was a conscious attempt to locate the affected animals and treat them before the ovaries had been cystic as long as a month. The animals encountered by the cooperating veterinarians in their practice, on the other hand, had usually shown the condition for a greater period of time. Undoubtedly, however, many of the more chronic cases had been sent to slaughter without the veterinarians having an opportunity to attend them. These disturbing factors in the main tended in the observed population to increase the proportion of animals which had shown the condition for a relatively short time and thus decrease the proportion showing it a longer time over that which should be found in a natural population. If the spontaneous recovery rate were as high as 77% every 31 days, the chances in a natural population of finding among nymphomaniac cows an animal that had shown nymphomania between 3 and 12

months is calculated to be approximately 1.22 in 100.[5] In the observed population, however, there were 12 out of 71, or approximately 17 in 100. Likewise, 2 of the 71 observed animals had shown nymphomania for a year and if the observed recovery rate were spontaneous, the chances of finding one such animal should be approximately one in thirteen million.[6] Therefore, it would seem that spontaneous recovery of such a high rate in the injected animals is highly unlikely on the basis of the observed distribution.

Some data are available on the rate of recovery under recognized methods of treatment. Mr. Howard Clapp (personal communication) has furnished data on 30 animals in which the cysts were broken down as often as signs of nymphomania recurred (usually within three days after recurrence) and of these, 13 showed the presence of corpora lutea within approximately 31 days. Williams and Williams (1923) reported 30 cases in which the cysts were broken down at irregular intervals and, in addition, adrenalin was used in some cases. Some difficulty is encountered in interpreting their data, but apparently only 7 out of 30 cases recovered within 31 days following such a plan of treatment. A comparison of the data on pituitary injections with the above two sets of data, using only first injections on the nymphomaniac cows with normal genital tracts, shows 55 out of 71 animals as forming corpora lutea within 31 days as compared with 20 out of 60 from the above data (77% as compared to 33%). On this basis alone it would appear that the intravenous injection of this pituitary extract does show a definite effect in causing the formation of corpora lutea in less time than occurred otherwise, if not also in increasing the proportion of animals which will eventually form corpora lutea.

Summary

An unfractionated extract of sheep pituitary gland was injected intravenously into 96 cows with cystic ovaries. Eighty-one of these animals showed nymphomania at the time treatment was begun, but the symptoms disappeared in 72 after a single injection. Symptoms recurred during the observation period in 14 of them. Six of these recurrences were from the 12 animals that showed uterine or tubal pathology. Corpora lutea are known to have been formed in 74 of the 96 animals within 31 days after treatment. Normal estrus has been shown by 69 of them since the single injection. Of the 53 animals bred following a single injection out of 84 showing no recog-

$$\frac{\sum_{x=3}^{11}(1-0.77)^x}{\sum_{y=0}^{\infty}(1-0.77)^y} \qquad \frac{(1-0.77)^{11}}{\sum_{y=0}^{\infty}(1-0.77)^y}$$

nized uterine or tubal pathology 36 have become pregnant. Six of the 12 animals showing abnormalities of the genital tract have been bred but none have become pregnant.

Re-treatment of 16 animals either because the cysts persisted after the first injection or because they recurred sometime later resulted in 6 additional pregnancies, all among the animals with normal genital tracts. A third injection was given to 3 animals but resulted in no pregnancies.

Evidence is introduced in the discussion to the effect that these results show a positive action of the pituitary gonadotrophin upon cystic ovaries.

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RENTAL RATE PLAN FOR BULLS USED IN ARTIFICIAL INSEMINATION[1]

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EARLY in the active operation of New Jersey's first Cooperative Artificial Breeding Unit, a plan of constructive breeding was arranged. This plan included an agreement that Rutgers University through its Dairy Research Station should furnish related superior proved sires and some unproved sires of similar blood lines as a source of semen. The bulls were approved after selection by a committee on a lease basis. Sires that had five or more daughters were leased at the rate of three dollars per acceptable[3] semen sample. Bulls that were partly proved, i.e., had one or more promising milking daughters, were paid for at the rate of two dollars per acceptable semen sample. Unproved bulls were sometimes leased at one dollar per sample, and very young sires were loaned outright without compensation. The Breeding Unit was responsible for feed and for housing and management of the sires. The method of arriving at a rate of lease was based upon a rental rate approximately high enough to permit the writing off of the appraised value of the bull in three to five years, when semen collections were made from 50 to 75 times a year.

As the Breeding Unit expanded some member breeders offered related sires which were selected by the committee for use in the program. Much controversy began at this time as to what constituted a satisfactory lease plan for bulls used in Artificial Insemination Units.

On June 1, 1943, the Association accepted a rental plan submitted by the authors which was based on performance for selected proved bulls and pedigree performance for unproved bulls acceptable to the committee. All charges are on the basis of each acceptable semen sample collected by the technician of the breeding unit. The base charge for selected proved bulls having five or more daughters is $3 per semen sample. In addition, 10 cents per point[4] is allowed for each percentile the daughter's average yearly fat record is above the breed average[5] in total fat for age and class. Using the breed average as 100 percent one can arrive at the point value and rental rate as follows: Add fat records of all daughters of varying ages; next, obtain total of equal number of fat records using breed average for age and class of

[1] Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, department of dairy husbandry.

[2] New Brunswick, N. J.

[3] Concentration and motility of sperm indicating fertilizing capacity.

[4] Point is percent.

[5] Breed averages for fat production in age and class are furnished by the National Breed Associations.

each daughter of the bull in question. Divide total of daughters' actual fat records by total of breed average fat records, and the resulting quotient shows the point rating of the bull. His rating above 100 percent when multiplied by 10 cents a point gives the additional sum which may be added to the base charge of $3 to determine his rental rate. (See Pedigree 1 in figure 1.)

Figure 1. Pedigree 1. Cooperative Artificial Breeding Ass'n No. 1, Inc., Pedigree.

Name: NJES Sensation Charlot Conqueror 673525
Born: February 22, 1933
Breeder: N. J. Experiment Station, Sussex, N. J.
Owner: N. J. Experiment Station, Sussex, N. J.

BULL

His fat test index of 4.36 is first among bulls with 22 or more daus. His 24 herd test daus. Average 15,630 lbs. milk and 611 lbs. Fat—3.9% test on mature 3X basis. He ranks 5th among 950 indexed bulls with his 706 lbs. fat index for bulls with 22 or more daus.

Base Rate	$3.00
Score 122%* =	*2.20
Rental Rate	$5.20

SIRE

Ormsby Sensation 45th Gold Medal, 442551

1927 N. Y. State Exp. 1 prize.

1931 Leading honor list sire

1931, 33, 34: 1 prize get of sire at East.

States exp. 1932: One reserve all-Amer. dau. 42 herd test dau. av. mature basis 3X 16,940 lbs. M., 610 lbs. F., 3.6% test.

DAM

Newmont Charlotte Ormsby 1457528

Herd improvement records 5 y 7 m Cl. B 326 d., 19,580 lbs. milk, 629.5 lbs. fat, 6y 8 m Cl. C 361 d., 13,038 lbs. milk, 448.7 lbs. fat.

GRAND SIRE

Ormsby Sensation 274343

23 arso daus. av. M. B. basis.

19,340 m. 653.87 F.

3.38% test one of the greatest bulls of the breed.

GRAND DAM

Shady Maple King Pontiac Hockster 319580

295 D. (CC. 233D).

15138.2 M 3.77% 571.52 F. at 5y 7 m.

GRAND SIRE

Ormsby Sensation 45th 442551

Gold medal bull—1931. Leading honor list sire.

1931, 33, 34: 1 prize get sire at East. States Expos.

1932. One reserve all-Amer. dau. 42 herd impr. dau. av. M. B. basis 3 times milked, 16,940 m, 610 f.—3.6% test. His index of 768 lbs. fat is 2nd among 950 bulls with 22 or more daus.

GRAND DAM

Woody Hill Charlotte Pontiac 882031

* This bull's 22 daughters average 122% of the breed average for fat for respective ages and classes.

The method of compensation for unproved bulls allows a base rate of 50 cents per acceptable semen sample for a yearling bull with a 25 cent annual

Figure 2. Pedigree 2. Cooperative Artificial Breeding Ass'n No. 1, Inc., Pedigree

Name: New Center Ormsby Alice 799799
Born: March 17, 1938.
Breeder: William Davis, Somerville, N. J.
Owner: William Davis, Somerville, N. J.

BULL

This bull has been brought back into the association because of the promise of his daughters, and the continued long life production and reproduction of his great dam.

Base Rate	$1.50
Scores	1.17
Rental Rate	$2.67

SIRE

NJES Sir Mutual Ormsby Jewel Alice 654594

His 43 daughters on herd test average class B (3X) mature—fat 594.00, milk 15630.00, test 3.8. These daughters average 59 lbs. more fat than their dams. He raised test 3 points. More than 450 cows became pregnant to him in the no. 1 breeding association in 1938, 1939 and 1940.

Score 125 = $.25.

DAM

Moly Segis Ormsby Ona 1619204

D.H.I.A. records. Class C 2 yrs.

Fat 545.80 milk 12516.00. Life Test 4.2. 3 yrs. fat 523.90. Milk 12539.00. 4 yrs. fat 457.30. Milk 9692.00. 5 yrs. fat 610.00. Milk 14442.00 6 yrs. fat 752.70. Milk 17167.00. 8 yrs. fat 589.00. Milk 1424.00. 9 yrs. fat 645.30. Milk 15824.00. 10 yrs. fat 669.50. Milk 15789.00.

Score 167 = .67.

GRAND SIRE

Newmont Mutual Ormsby Lad 443889

His 28 daughters on herd test average on nature 3X basis—fat 555.00, milk 15,300.00, test 3.63.

Score 118 = $.09.

GRAND DAM

Newmont Ormsby Jewel Alice 1239022

Herd test record: class B fat 636.60, milk 16,712.00, test 3.81.

Score 127 = .135.

GRAND SIRE

King Ona Ormsby 2nd 505582

One of New Jersey's best proved sires. His 20 daughters averaged on mature 10 months, 2X milked basis 450 lbs. fat and 12,500 lbs. milk on D.H.I.A. test.

Score 102.5 = .025.

GRAND DAM

Bloomingdale K. F. Molly Segis 1317296

D.H.I.A. record on 2X milking—11 mos.—4 yrs. fat 409.50, milk 10390.00.

Score 100.

increase to $1.50 at five years of age. In addition there is an allowance of one cent per point for the sum that the records of sires' daughters, dam, and/or dams' daughters may average above the breed average, plus one-half cent a point that may be accumulated from the first grandparental generation on the same comparative basis. (See pedigree 2 in figure 2, table 1).

For bulls having one or more daughters and less than five, the extra rate of compensation is 8, 6, 4, or 2 cents per point that the average production

of all daughters is above the breed average but in a descending scale from five to one daughter. As an example, the bull shown in pedigree 2 had on October 1, 1943, two daughters with records with an average point value of 120 percent. He, being five years old, was credited with a rental rate as follows—(20×$.04: fat production value)+($1.50: his age rate)+($1.17: his pedigree value)=$3.47 per semen sample. (See pedigree 2 in figure 2, and table 1.) When this bull has five proved daughters, his earning capacity

TABLE 1. RENTAL RATE PLAN FOR BULLS USED IN NEW JERSEY BREEDING ASSOCIATION NO. 1

Earning rate for proved bulls

2¢ per point that first daughter's fat production is above the breed average for age and class.
4¢ per point that first 2 daughters' average production is above the breed average for age and class.
6¢ per point that first 3 daughters' average production is above the breed average for age and class.
8¢ per point that first 4 daughters' average production is above the breed average for age and class.
10¢ per point that first 5 (or more) daughters' average production is above the breed average for age and class.
Base charge for worthy Proved Bulls—Those with 5 or more records daughters—$3.

Earning rates for unproved bulls

1 to 2 yrs. old—$.50+1¢ per point earned by parents and ½¢ per point earned by grandparents.
2 to 3 yrs. old— .75+1¢ per point earned by parents and ½¢ per point earned by grandparents.
3 to 4 yrs. old—1.00+1¢ per point earned by parents and ½¢ per point earned by grandparents.
4 to 5 yrs. old—1.25+1¢ per point earned by parents and ½¢ per point earned by grandparents.
5 yrs. and over—1.50+1¢ per point earned by parents and ½¢ per point earned by grandparents.

will immediately be reckoned on the vasis of the daughters' average production in fat for age and class, as compared to the breed average.

The above plan has now been in operation for all classes of bulls mentioned for 8 months. During this time one unproved bull has become proved and his rental rate plan has changed from $3.40 per acceptable semen sample to $5.30.

Members of the association recognize the significance of performance records in the pedigrees of the bulls used. The earning rates of bulls will continue to change and will require frequent corrections. It is believed that this will be an incentive for owners of bulls to keep records up to date. Revisions in this plan will no doubt be required as the breeding program progresses.

ON THE MECHANISM OF NON-PROTEIN-NITROGEN UTILIZATION BY RUMINANTS[1]

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IN A previous publication (Johnson, Hamilton, Mitchell and Robinson, 1942) from this laboratory, a mechanism of urea utilization was postulated as a symbiotic relationship in which a considerable proportion of the nitrogen of the feed was converted in the rumen into micro-organismal protein. The protein of these microorganisms is digested by the ruminant as it passes through the abomasum and duodenum, in the same manner as any other preformed protein. In this manner the ruminant actually would digest approximately the same type or quality of protein irrespective of the nitrogen source, provided the total nitrogen consumed did not exceed the maximum amount which the microorganisms could utilize. Nitrogen in excess of that required by the microorganisms should have a biological value for the ruminant comparable to that for a non-ruminant of similar requirement.

The authors' previous work, indicating the similarity in the utilization of the nitrogen of urea, soybean oil meal, and casein by sheep, when these sources of nitrogen were added to a basal ration not to exceed the equivalent of 12 percent protein (N×6.25), is consistent with the theory just postulated. The theory receives added support, as pointed out in a previous publication of the authors, from the fact that a number of investigations by other workers has failed to find significant differences in the biological values of a wide variety of proteins when fed at comparatively low levels to ruminants. In fact, the frequent and consistent observations that the biological value of the proteins of different feeds approximates 60, seem more than merely coincidental.

The ciliate infusoria of the rumen were first described by Gruby and Delafond (1843). They are normally present to the extent of about a million per cc. of rumen material and have been classified into more than 30 different species. Smaller numbers of flagellates and amoebae are also present in the paunch. Ferber and Winogradowa-Federowa (1929) state that there are

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2,700 million or about three kilograms orf protozoa in the normal sheep's rumen. On examination of the contents of the true stomach or abomasum, however, large numbers of fragments of protozoa but no whole protozoa were found. According to Mangold (1933), the proportion of food protein metabolized by infusoria and recovered by subsequent digestion of the infusoria cells is considerable. Perhaps the most obvious explanation for the disappearance of the protozoa in the abomasum is that these organisms are digested by the gastric juices secreted there. Obviously then the digestibility and biological value of the proteins in the infusorial cells would be of interest since these proteins are being used by the ruminant.

Another possible symbiotic relationship existing in the rumen may be between the smaller bacteria and the protozoa. Since it is difficult to grow the latter *in vitro* in a medium free of preformed protein, it seems possible that the protozoa of the paunch are normally nourished by the bacteria. It thus seems possible that, under conditions of urea feeding, it is the bacteria that first synthesize protein for their own needs from the non-protein source, then the protozoa feed upon the bacteria protein, and finally the host is nourished by the protein of the protozoa.

It was of interest, therefore, to study the utilization of urea nitrogen by the ruminant under such conditions that the rumen was maintained free of protozoa. Experiments also were planned to study the biological values of the proteins of the bacteria and of the protozoa normally found in the paunch of sheep.

Availability of Urea to Defaunated Sheep

After considerable testing of various defaunation procedures, a modification of the fasting-$CuSO_4$ technic of Becker, Schulz and Emmerson (1930) was adopted. Growing lambs were kept individually in the metal-covered metabolism crates long used in this laboratory. The walls, floors, and feeding containers were washed daily with hot water and weekly with a two percent $CuSO_4$ solution. Feed was heated for 48 to 72 hours at 65° C. previous to feeding. The lambs were first fasted for 48 hours, then given by stomach tube one pint of water containing 50 cc. of 2 percent $CuSO_4$. Twenty-four hours later the lambs again were given the $CuSO_4$ treatment. At the end of this treatment, the paunch contents—a small amount of which can easily be obtained on the end of a stomach tube—were found to contain no protozoa. The $CuSO_4$ treatment was repeated once each week and for 30 days the paunch contents, examined every other day, were entirely free of protozoa. The technic of paunch examination was checked by using normal lambs, in which the presence of protozoa was readily and positively ascertained.

Using the procedure just described, six growing lambs were defaunated

and their paunches kept fee of protozoa for 30 days. For the last 14 days all lambs were on a constant food intake, and the last 7 days feces and urines were collected. The ration used during this test consisted of the following: corn molasses 35, corn starch 27, oat straw 32.5, bonemeal 1, salt 1, cod liver oil 0.25, Na_2SO_4 0.24, Fe_2O_3 0.01, and urea 3. The percentage of conventional protein (T.N. $\times$6.25) was 11.2, 83 percent of which was in the form of urea. The pertinent data are given in table 1. According to these data, the nitrogen of this ration, 83 percent of which was in the form of urea, had an average apparent digestibility of 68.4 percent and an average biological value of 49. The apparent digestion coefficient was well within the range

TABLE 1. AVAILABILITY OF UREA NITROGEN BY DEFAUNATED LAMBS

Lamb number	Body weight lbs.	Crude protein in ration pct.	Nitrogen intake		Apparent digestibility of nitrogen pct.	Nitrogen balance		Estimated biological value of nitrogen[1] pct.
			Total per day gms.	As urea pct.		Total per day gms.	As pct. of absorbed nitrogen	
3360	79.5	11.2	9.643	83.0	69.1	1.102	16.5	52
3305	68.5	11.2	9.643	83.0	73.6	1.493	21.0	51
3470	71.5	11.2	9.643	83.0	72.8	1.145	16.3	48
3649	69.5	11.2	9.643	83.0	62.8	0.244	4.0	45
3488	68.5	11.2	9.643	83.0	71.6	1.256	18.2	50
3262	81.0	11.2	9.643	83.0	60.5	0.333	5.7	48
Averages					68.4			49

[1] Using the following factors which were obtained during a N-free diet feeding period immediately following the defaunation test and using the same lambs: Metabolic N in feces = 5.563 mgm. per gram of dry matter consumed; Endogenous N = 1.252 gm. per 100 lb. live weight or 0.0275 gm. per kg. live weight.

previously reported (Johnson, Hamilton, Mitchell and Robinson, 1942) from this laboratory for rations containing varying proportions of urea nitrogen added to either soybean protein or to casein.

The calculated biological value of 49 is lower than those generally obtained on mixtures of nitrogen from urea and preformed proteins of feeds as reported in our previous paper. However, it does agree with those biological values reported by Harris and Mitchell (1941) when their sheep were getting equivalent amounts of nitrogen from a urea-casein ration.

The nitrogen balances, expressed as a percent of the nitrogen absorbed, varied from 4.0 from one lamb to 21.0 for another. These values also compare favorably with similar data previously published.

Thus on medium levels of protein intake, defaunated sheep utilize the nitrogen of rations to about the same extent as do normal sheep. It is concluded that the bacteria in the paunch of ruminants can synthesize non-protein nitrogen into their own cellular proteins. While these proteins can

be subsequently digested by the digestive enzymes secreted in the digestive juices of the host, it is quite probable that ordinarily much of it is first utilized by the protozoa and the protozoal protein subsequently digested by the host.

Digestibility and Biological Value of the Proteins of Rumen Protozoa and Bacteria When Fed to the White Rat

In order to determine the digestibility and the biological value of the proteins in rumen protozoa and bacteria, it was first necessary either to grow the organisms in pure culture or to isolate them from rumen contents, uncontaminated by food residues. With bacteria, both isolation and culture methods were used. For the isolation of a bacterial fraction, fresh rumen contents, obtained from normal sheep and cattle immediately after slaughter, were diluted ten to one with water, strained through a wire screen and rinsed. The sludge was then centrifuged at such a speed as to throw out most of the remaining food particles and the protozoa, leaving most of the bacteria in the supernatant liquid. The bacteria were then separated by centrifugation at high speed in a Sharpless Supercentrifuge. The bacteria were resuspended in water and again separated by centrifugation, then dried at 40° C. in a vacuum oven. In this manner approximately 80 grams of dried bacteria were obtained.

Before obtaining a bacterial culture for growth on synthetic media, samples of paunch contents were aseptically taken, by means of a No. 12 hypodermic needle inserted into the paunch from the left side of sheep on normal as well as urea-containing rations. All cultures were plated out on a medium containing either urea or ammonium sulfate as the sole source of nitrogen. Eight different organisms, both rods and cocci, were isolated in pure culture. There was no evidence obtained that the urea fermentative flora was modified by urea feeding of the sheep.

One of the organisms isolated in pure culture, a yellow rod, presumably a flavobacterium, was grown in 15 liter batches on the following medium with aeration:

K_2HPO_4	3.1 gm.
KH_2PO_4	0.8 "
KCl	0.2 "
$MgSO_4 \cdot 7H_2O$	0.2 "
$FeSO_4 \cdot 7H_2O$	0.01 "
$MnSO_4 \cdot 4H_2O$	0.01 "
Glucose	10.00 "
Urea	1.00 "
Water	1000.00 cc.

(One gram urea or 1.5 gram ammonium sulfate and 5.0 grams agar were also used in plating.)

From the plates, colonies were isolated and transferred to 10 cc. tube cultures of the liquid media. These were incubated 2–3 days and transferred to one liter flasks fitted for aeration. After 2–3 days growth in the liter flasks, transfer was made to 15 liter pyrex carboys and again incubated with aeration for 4 days. The suspension was then centrifuged in the supercentrifuge, the cells resuspended in water, recentrifuged, and finally dried in a vacuum oven at 40° C. In this manner, about 80 gms of dried bacteria were obtained.

Obtaining considerable quantities of ciliates was much more difficult since they could not be cultured. The isolation procedures described by Ferber (1928) and by Mansuardi (1931–32) were tried without success. The following procedure was found to be satisfactory.

Rumen contents, obtained immediately after slaughtering either cattle or sheep, were diluted with approximately one-third their volume of warm water, mixed thoroughly, and the liquid pressed out through coarse cloth. The feed residue was discarded and the expressed liquid allowed to stand for three or four hours, during which time most of the protozoa would settle to the bottom in a grey-white layer. Some finely divided feed particles collected at the top and were skimmed off. The liquid was siphoned off and the layer of protozoa, mixed with water, was filtered through a 200-mesh sieve. The protozoa were again allowed to settle, the supernatant liquid removed, and the process repeated until the supernatant liquid was clear. In this manner a layer of protozoa, free from feed residues and bacteria was obtained. The protozoa were dried in a vacuum oven. About 80 grams of dried protozoa were obtained.

While time did not permit the preparation of sufficient amounts of the various micro-organisms for exhaustive studies, enough of each was prepared for the determination of the biological value of the proteins of the protozoa with two rats, of the bacteria isolated from the rumen with three rats, and of the bacteria grown on synthetic media with three rats. The method used for the determination of the biological values was the same as that developed by Mitchell in this laboratory. The percentages of protein in the diets were 10.56, 10.75 and 18.00 for the rumen protozoa, rumen bacteria, and cultured bacteria rations respectively.

The pertinent data and the calculated digestion coefficients and biological values of the proteins are given in table 2.

The dried protozoal fraction contained 54.75 percent crude protein, the bacterial fraction isolated from rumen contents contained 44.50 percent crude protein, while the cultured bacterial fraction contained 58.81 percent crude

TABLE 2. BIOLOGICAL VALUES AND DIGESTIBILITY FOR RATS OF THE PROTEINS IN FRACTIONS OF RUMEN PROTOZOA AND RUMEN BACTERIA AND OF RUMEN BACTERIA GROWN ON SYNTHETIC MEDIA

	Test on rumen prozotoa				Test on rumen bacteria						Test on cultured bacteria					
	Protozoa		Beef		Bacteria			Beef			Bacteria			Beef		
Crude protein in preparation, pct.	54.75	54.75	86.00	86.00	44.50	44.50	44.50	86.00	86.00	86.00	58.81	58.81	58.81	86.00	86.00	86.00
Crude protein in diet, pct.	11.56	11.56	11.62	11.62	10.75	10.75	10.75	10.88	10.88	10.88	18.00	18.00	18.00	18.00	18.00	18.00
Rat number	227	228	227	228	202	203	204	202	203	204	199	200	201	199	200	201
Average body weight, gms.	75	105	106	79	65	98	66	105	80	106	72	113	75	106	87	108
Daily food intake, gms.	8	7.41	8	8	7	7	7	7	7	7	7	7	7	7	7	7
Nitrogen intake, mgm.	148.0	137.1	148.8	148.8	120.4	120.4	120.4	121.8	121.8	121.8	205.1	205.1	205.1	203.7	203.7	203.7
Fecal nitrogen, mgm.	31.2	29.8	9.9	9.6	63.8	58.4	63.5	8.6	9.6	8.5	47.3	38.2	46.7	8.5	9.0	9.5
Food nitrogen in feces, mgm.	19.0	20.2	0	0	56.7	50.1	56.2	1.6	1.3	1.2	38.6	30.7	38.8	0	1.5	1.6
Nitrogen absorbed, mgm.	129.0	116.9	148.8	148.8	63.7	70.3	64.2	120.2	120.5	120.6	166.5	174.4	166.3	203.7	202.2	202.1
Urinary nitrogen, mgm.	53.6	71.4	61.1	49.9	35.8	51.8	34.4	57.4	50.2	58.1	123.6	118.2	119.4	95.4	102.3	101.4
Food nitrogen in urine, mgm.	32.3	46.5	33.5	30.3	19.0	30.9	17.5	33.3	32.3	33.7	105.4	94.3	101.6	71.2	82.7	77.9
Nitrogen retained, mgm.	75.3	45.5	87.7	98.9	27.9	18.5	29.8	62.8	70.3	72.5	42.9	56.2	46.9	108.3	99.9	100.7
Endogenous nitrogen, mgm.	21.3	24.9	27.6	19.6	16.8	20.9	16.9	24.2	17.9	24.4	18.2	23.9	17.8	24.2	19.6	23.5
Nitrogen utilized, mgm.	96.6	70.4	115.3	118.5	44.7	39.4	46.7	86.9	88.2	86.9	61.1	80.1	64.7	132.5	119.4	124.3
Digestibility, pct.	87.2	85.3	100	100	52.9	58.4	53.3	98.7	98.9	99.0	81.2	85.0	81.1	100	98.6	99.2
Digestibility, average, pct.	86.2		100			54.9			98.9			82.4			99.3	
Biological value, pct.	75	60	77	80	70	56	73	72	73	72	37	46	39	65	59	62
Biological value, average, pct.	68		78			66			72			41			62	

protein. This value is of the same order as that reported by Hopkins, Peterson, and Fred (1929) who reported an average of 57 percent protein in 25 species of bacteria. While the bacterial fraction isolated from the rumen probably contained a wider variety of organisms than did the cultured fraction, the lower percentage of protein in the former compared with that in the latter was probably due, not to a different protein content of the bacteria themselves in the two fractions, but to some contamination with food particles. The presence of 1.36 percent crude fiber in the rumen fraction, in contrast to but 0.25 percent in the cultured fraction, points to the same conclusion.

The true digestion coefficients of the protein were, for the three fractions, rumen protozoa, rumen bacteria and cultured bacteria, 86.2, 54.9, and 82.4 percent, respectively. The lower digestibility of the protein in the rumen fraction can probably be explained also on the basis of some food contamination. The reasonably high digestibility of the proteins in the protozoal fraction and the cultured bacterial fraction compares favorably with the digestibility of many animal proteins.

The biological values were more variable than desired but the averages were 68 for the protozoa protein and 66 for the rumen bacteria. While slightly higher than the average of 60 which is generally approximated for proteins from all sources when fed to sheep at low levels, these biological values are not greatly out of harmony with the hypothesis that most of the feed protein, when fed to sheep at low levels, is first transformed into microorganismal protein. These results would indicate that there is little, if any, difference in the biological values of paunch protozoal and of bacterial proteins.

The low biological value of 41 for the proteins in the cultured bacteria is probably explained on the basis of the high concentration of protein (18.00 percent) in the ration fed. It is a well-known fact that the biological values of a protein decreases as the percentage of protein in the diet increases. For this reason it is now customary in this laboratory to compare the biological value of the protein to be tested with that of a standard dried-beef protein. In such a test paired rats in a reversal method were fed equal daily amounts of feed containing the same percentages of protein. Thus in the test on the protozoal fraction, the average biological value was found to be 68, and the biological value of beef protein averaged 78. Similar comparative biological values for bacterial protein, isolated from rumen contents, and beef protein, when both were fed at about an 11 percent protein level, were 66 for the former and 72 for the latter. When bacterial protein (cultured) and beef protein were fed at an 18 percent level, the biological value of the bacterial protein averaged 41 and that of beef protein averaged 62. Changing the per-

centage of beef protein from 11 to 18 decreased the biological value by at least 10 percentage points, while a corresponding change in the percentage of bacterial protein resulted in a decrease of at least 25 percentage points. To what extent this latter decrease was due to the increased percentage of protein in the diet is not known, but that probably was the chief contributing factor rather than any difference between the isolated and cultured fraction.

These data indicate that both bacterial and protozoal proteins are quite digestible and are of fairly good quality. Their biological values support the microorganismal theory of nitrogen utilization by ruminants. They furnish no evidence of the superiority of protozoal protein over bacterial protein.

Further Evidence of the Symbiotic Relationship Between Bacteria and Protozoa in the Rumen

If the symbiotic relationship between bacteria and protozoa exists, as previously suggested, an increase in the number of bacteria and an increased rate of bacterial fermentation might be expected immediately to follow the consumption of food by a ruminant. As the numbers of bacteria increased, thus making a larger food supply for the protozoa, the protozoa should flourish and their numbers increase, probably causing a decrease in bacteria. Such evidence was obtained in the following manner.

Two wether lambs were used in the study of methane production following feeding. One lamb was maintained for several days on a urea ration and the second lamb was maintained for the same period of time on a casein ration. After several days on the same level of food, each lamb in turn was placed in a pneumatic chamber (Steuber, 1930; Keilholz, Compiler, 1933) used in this laboratory to study respiratory exchange in swine and sheep, for a period of nine hours immediately following feeding. The rations were then reversed and the study repeated in the same manner. While the lambs were in the chamber, gas samples were removed at hourly intervals, each sample representing a 20-minute period of respiratory exchange. The methane produced during a 20-minute period at hourly intervals is tabulated in table 3. These figures show that a maximum methane production occurred during the first hour, there being no difference traceable to the type of ration fed. Fermentation decreased more or less regularly from the second hour for three or four hours and then less consistently for nine hours, at the end of which time the methane production had decreased at least 50 percent or more. These data are in agreement with those of Magee (1924) who found that the fermentation heat rises rapidly during the first hour after feeding and then falls off gradually during the next three hours.

Bacterial and protozoal counts were also made on rumen contents taken

by hypodermic needle from lambs maintained on a urea ration. Samples were taken from three lambs at various intervals up to 24 hours after feeding and the averages tabulated in table 3. The bacterial counts were made by the plate method while the protozoal counts were made by diluting rumen contents ten times and staining with formol-iodine or with methylene blue. A hemocytometer was used in making all counts, and each was made in quadruplicate.

The greatest number of bacteria and the smallest number of protozoa were

TABLE 3. COUNTS OF BACTERIA AND PROTOZOA IN RUMEN CONTENTS AND METHANE PRODUCTION AT INTERVALS FOLLOWING FEEDING

Time after feeding hrs.	Methane production in liters per 20 minutes				Protozoa[1] per cc. ×1000 urea	Bacteria[1] per cc. ×1000 urea	Yeast-like organism per cc.×1000 urea
	Lamb 1 urea liters	Lamb 1 casein liters	Lamb 2 casein liters	Lamb 2 urea liters			
1	0.58	0.59	0.46	0.43	450	6,500	83,500
2	0.45	0.36	0.38	0.34	—	—	—
3	0.34	0.30	0.37	0.19	—	—	—
4	0.31	0.21	0.23	0.19	525	3,000	78,560
5	0.31	0.16	0.22	0.19	—	—	—
6	0.29	0.21	0.23	0.19	—	—	—
7	0.30	0.11	0.26	0.19	515	3,500	63,400
8	0.30	0.20	0.25	0.19	—	—	—
9	0.21	0.19	0.29	0.18	—	—	—
16	—	—	—	—	840	500	25,750
18	—	—	—	—	770	500	25,500
24	—	—	—	—	674[2]	—	35,000[2]

[1] Average of three lambs on urea ration.
[2] Mostly (about 75 pct.) dead.

found at the end of the first hour after feeding. There was a decrease in the numbers of bacteria and an increase in protozoa at the fourth hour and these reciprocal changes seemed to continue for at least 16 hours, at which time the number of bacteria was one-thirteenth that at the end of the first hour and the number of protozoa had doubled approximately. While no great degree of accuracy can be claimed for these figures (in particular for the bacterial counts which are manifestly too low), they are of relative value and do furnish additional confirmatory evidence in favor of the symbiotic relationship between bacterial growth and protozoal growth suggested above.

Continued fasting of a ruminant causes a decrease in both bacteria and protozoa. In respiration work with steers in this laboratory, only traces of methane are found in chamber air during the 4th, 5th and 6th days of fast.

In the defaunation work reported above, rumen contents were practically free of protozoa after two days fast in lambs. Ferber (1928) has also reported that after 5 days fast there are no infusoria in the rumen. The lack of methane production indicates little or no bacterial metabolism and the decreased numbers of protozoa would be expected to follow an insufficient food supply.

Axelsson (1942) has reported the importance of certain yeast species in rumen protein synthesis. In this work an organism (illustrated at 70×

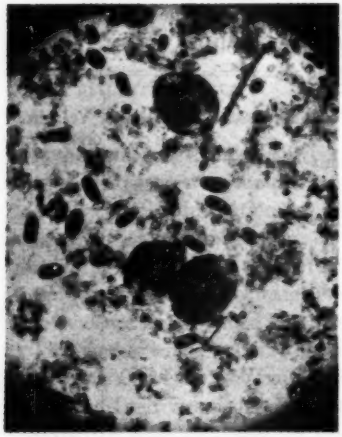

Figure 1 (left). 70× magnification. This photomicrograph illustrates several of the ciliates commonly found as well as showing the tremendous number of yeast-like organisms in the background.

Figure 2 (right). 280× magnification. This figure illustrates the yeast-like organisms and shows several examples of fission.

and 280× in figures 1 and 2) which had the appearance of a Schizosaccharomycete was found in very large numbers. However, this organism did not grow on Sabouraud's medium and a definite identification could not be made. Direct counts were obtained in the same manner as for the protozoa and are also reported in table 3. They seem to follow the same trend as the bacteria.

Summary and Conclusions

1. Defaunated growing lambs utilize the nitrogen of urea-containing rations to about the same extent as normal growing lambs. The average digestibility of the nitrogen in a ration, in which 83 percent of the total nitrogen was in the form of urea, was 68.4 and the biological value 49.

2. Protozoa may be separated from paunch contents in a fairly high state of purity by mechanical procedures of filtration and centrifugation. The dried protozoa fraction, isolated from paunch contents, contained 54.75 percent crude protein. Protozoal protein, when fed to rats, had a true digestibility of 86.2 percent and a biological value of 68.

3. A fraction of bacteria was isolated from paunch contents less satisfactorily than were the protozoa. The bacterial fraction isolated contained 44.50 percent when dried, while a bacterial fraction, obtained by culture on synthetic media, contained 58.81 percent protein. The digestibility of the protein in the purer preparation was 82.4 percent. The biological value of bacterial protein, when fed to rats at a level similar to that at which the protozoa were fed, was 66 percent.

4. Methane production in sheep is highest during the first hour following feeding, decreases for three to four hours quite rapidly, and then slowly. Nine hours after feeding either a urea or casein ration to growing lambs the methane production had decreased about 50 percent or more.

5. Bacterial and protozoal counts, in paunch contents made at intervals for 24 hours following feeding, showed the greatest number of bacteria and the fewest protozoa one hour after feeding. At succeeding intervals, the numbers of bacteria decreased while the numbers of protozoa increased more or less regularly for 16 hours. One hour after feeding, 6,500,000 bacteria and 450,000 protozoa per cc. of paunch contents were counted; 16 hours later but 500,000 bacteria and 840,000 protozoa per cc. were counted. A yeast-like organism was also observed to be present in paunch contents in very large numbers.

6. The data presented here are in agreement with the hypothesis that in ruminants much of the food nitrogen, whether of protein or of non-protein nature, is first synthesized by the bacteria into their own cellular proteins, and then, at least to a considerable extent, the protozoa utilize bacterial protein in their own growth, and finally the host digests the protozoal protein, and remaining bacterial protein. Thus up to the maximum amount of nitrogen capable of utilization by the microorganisms in the paunch, all food nitrogen would exhibit a biological value characteristic of the mixed microorganisms reaching the abomasum and duodenum. This biological value seems to approximate 60. Nitrogen consumed above that required by the microorganisms should exhibit a biological value approximating (probably somewhat less) that of a non-ruminant of similar requirements.

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GROWTH OF STEERS ON SELENIFEROUS RANGE[1]

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IT IS now well known that "alkali disease" and "blind staggers" in range animals are forms of selenium poisoning. Many observations of the condition and symptoms of animals feeding on seleniferous ranges have been published (Beath et al., 1934 and 1934a; Franke et al., 1935; Moxon, 1938). Beath and co-workers have made extensive studies of the feeding habits of range animals and the symptoms of "alkali disease" and "blind staggers" associated with them (Beath et al., 1934a and 1935; Knight and Beath, 1937). In addition, they have conducted several short-term grazing and feeding experiments using seleniferous feeds. In all these experiments they have noted much variation in susceptibility of different animals to selenium poisoning and the type of symptoms produced by different sources of selenium. Most of the controlled experimental studies on selenium poisoning have been done with small laboratory animals; and have been reviewed by Moxon (1937) and Moxon and Rhian (1943).

It has been reported that in areas where plant poisonings are common, native animals tend to avoid poisonous plants (Beath, 1931) and eat them only as a last resort. Beath et al. (1935) noted that in areas where many cases of acute poisoning and "blind staggers" occurred the two-grooved milk vetch (*Astragalus bisulcatus*) was common. Therefore, in an area where the vetch comprised approximately 80 percent of the forage cover sheep were forced to graze on this plant in a fenced enclosure for six weeks. No symptoms of "blind staggers" occurred. When steers were put in the enclosure they refused to eat the vetch and could not be kept confined (Beath et al., 1935). It is now known that the failure of these vetches to produce poisoning was due to the fact that they were growing on soil relatively free from selenium. In other instances (Beath et al., 1935) plants containing relatively large amounts of selenium have been fed to cattle, sheep, and pigs without producing symptoms similar to those reported for "alkali disease" by Franke et al. (1935). In another experiment barley hay containing 6 p.p.m. of selenium was fed to cattle for several months with no noticeable effects, and saltbush, averaging 19 p.p.m. selenium was fed to cattle and hogs for three months with no harmful effects (Beath et al., 1935). Feeding

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of wheat and barley containing a few p.p.m. of selenium failed to produce "alkali disease" in cattle, sheep, and hogs (Beath et al., 1935). However, in a later experiment seleniferous barley caused typical symptoms of "alkali disease" in cattle in about six weeks (Beath et al., 1935). Two out of four steers, grazing on a range bearing *Oonopsis*, woody aster and *A. bisulcatus* developed symptoms of poisoning. In one instance it was shown that cattle could tolerate wheat grass hay containing 15 p.p.m. selenium for six months with no ill effects (Beath et al., 1934a). Sheep have been fed winter fat (*Eurotia lanata*) containing 30 p.p.m. selenium as about 30 percent of their diet for three months with no apparent harm (Knight and Beath, 1937).

Under controlled feeding conditions Schoening (1936) and Moxon (1941) have produced typical symptoms of "alkali disease" in a limited number of pigs by feeding naturally seleniferous corn. By feeding relatively large amounts of sodium selenite symptoms of "alkali disease" have been produced in hogs by Miller and Schoening (1938) and in equines by Miller and Williams (1940).

Of the two types of selenium poisoning now recognized, "blind staggers" is most common in range areas west of South Dakota. This type of poisoning apparently affects the nervous system and the toxic effects develop rather rapidly. "Blind staggers" is probably caused by periodic ingestion of plants with a high selenium content. In South Dakota the "alkali disease" is the most common form of selenium poisoning. This type of poisoning is due to the continued ingestion of plants of low selenium content.

Since nearly all the knowledge of selenium poisoning under range conditions had arisen from observations made during surveys, it seemed desirable to study its occurrence and symptoms under controlled natural conditions.

Plan of Experiment

Through the cooperation of the Resettlement Administration,[3] a ranch in a seleniferous area was made available for grazing experiments. The ranch is located in Lyman County, South Dakota, in Sec. 2, T. 107 N., R. 78 W., and Sec. 35, T. 108 N., R. 78 W. The ranch selected was one on which, according to ranchers in the area, "alkali disease" had been very severe. All ranchers who had operated this ranch had experienced cattle losses from this cause. This history of selenium poisoning was substantiated by selenium analyses of soil and vegetation from different parts of the ranch. These preliminary analyses and subsequent detailed analyses of soils and vegetation for selenium have been reported (Moxon et al., 1939; Olson et al., 1942 and 1942a).

[3] The cooperation of the Resettlement Administration and the Soil Conservation Service in providing the ranch for this study is gratefully acknowledged.

The first grazing experiment was set up to study the growth and market quality of steers grazed in a seleniferous area when on under-grazed range, over-grazed range, normal range, and normal range plus arsenic-salt (salt to which arsenic was added). Since there is a popular belief (Beath, 1931) that animals raised on seleniferous range are more resistant to "alkali disease" than animals shipped into seleniferous areas, half of the experimental steers were purchased in the area of the ranch and the rest from a non-seleniferous area. Several times during the experiment, blood samples were taken for chemical analyses. The results will be published in another paper.

The steers that were used in this study were grade animals about one year old when started. Half of them were purchased in eastern South Dakota and were from non-seleniferous areas. The other half were purchased at a market near the ranch and had been raised in that general area of the state. The steers were divided into lots so that five from each source were in each of the four lots. The average weight of the steers in each lot varied by only 2.6 pounds.

Range surveys[4] of the quantity and quality of grasses indicated that approximately twenty acres of pasture per head would be normal grazing capacity for the area. To allow the use of ten steers in each of four lots, pastures of 100, 200, and 300 acres were fenced off. Lot I was allowed 100 acres of pasture, which was equal to 17.54 forage acres.[5] This was a little more than one-half the normal requirement and was intended to force the steers to graze nearly all the vegetation. Lot II was allowed 300 acres of pasture equal to 44.77 forage acres, which was about one and one-half times the normal amount and was expected to permit free choice of grasses. Lots III and IV were alternated weekly between pastures III and IV (200 acres each) during the second year. Pasture III was equal to 27.05 forage acres and pasture IV was equal to 31.04 forage acres. It is significant that there were very few plants (such as *Astragalus bisulcatus*) that tend to accumulate large quantities of selenium in these pastures.

Two earthen dams were constructed to supply water for the cattle. Two lots had access to each pond, with fences to keep the lots separate. A deep well furnished water during the winter months.

All the steers had access to loose salt. Those in Lot IV were given an arsenic-salt mixture to determine its affect on animals grazing on a selenifer-

[4] The cooperation of the personnel of the U. S. Forest Service in assisting in the range surveys is gratefully acknowledged.

[5] A forage acre, as a standard of perfection, is an acre of forage having a 100 percent density of 100 percent palatable vegetation. A perfect density is based on a blue-grass lawn in well-kept condition.

The forage acre is used as a factor to convert range survey data into grazing capacity. The forage density times average palatability times acres equals forage acres. Forage acres divided by forage acre allowance per animal unit gives the grazing capacity for an area of acres.

ous range. From June to September, 1939, salt containing 5 p.p.m. of arsenic was provided; from September, 1939, to July, 1940, the salt contained 10 p.p.m. of arsenic and after that the salt contained 25 p.p.m. of arsenic.[6] Laboratory experiments had shown that small amounts of arsenic would counteract the toxic effects of selenium in rats (Moxon, 1938), in dogs (Rhian and Moxon, 1943) and in hogs (Moxon, 1941).

The cattle were weighed bi-weekly for the first three months and at monthly intervals thereafter. Blood samples were collected from the jugular vein at approximately monthly intervals. These were analyzed for hemoglobin, calcium, phosphorus, non-protein nitrogen, selenium, and arsenic (lot IV).

During the winters the cattle were allowed to graze in a pasture near the barns, when the weather permitted. The balance of the time they were fed western wheat grass hay and alfalfa hay in the yards. The western wheat grass hay was put up on a section adjacent to the ranch and contained from 2.0 to 4.2 p.p.m. of selenium. The alfalfa was grown on a seleniferous field about 15 miles from the ranch and contained 5.6 p.p.m. of selenium. Approximately twenty tons of western wheat grass hay and ten tons of alfalfa hay were fed during the winter. The cattle were separated in pens at night and were given salt in the pens. Lot IV had the arsenic-salt mixture and the other three pens had plain salt.

In September, 1940, two steers from each lot were sold. They were replaced with heifers to begin a study of the effects of selenium on reproduction. The remaining steers were left in their original lots until spring. In July, 1941, ten more heifers were put in the lots, five in lot III and five in lot IV. Two steers from lot II and one from lot IV were put in lot I and one from lot III and two from lot IV were put in lot III. There were then ten steers in each of the first two lots (lots I and II) and five steers and five heifers in each of the last two lots (Lots III and IV).

Results and Discussion

Data on the selenium content of the main forage grasses in the pastures have been published (Olson et al., 1942). *A. smithii* (Western Wheat Grass) was studied most thoroughly as it is the principal forage grass in the pastures. In general, the selenium content was of the same magnitude for the two years studied, 1940 and 1941. Marked variations could be accounted for by the number of samples collected and leaching of selenium in the draws (Olson et al., 1942). The average selenium content (in parts per million) of a

[6] In preparing the arsenic salt mixture, 1.83 grams of sodium arsenite ($NaAsO_2$) and approximately 23 grams of salt (NaCl) were ground in a mortar to secure intimate mixing. This salt and arsenic mixture and 100 pounds of loose stock salt were then thoroughly mixed in a small concrete mixer.

limited number of *A. smithii* samples taken in each of the pastures for the years 1940 and 1941, respectively, is: I—4.07, 6.15; II—12.84, 5.11; III—13.09, 5.38; IV—7.92, 5.89.

Perhaps the most interesting results noted in this experiment are that the steers made good gains on seleniferous range, the steers on the smallest pasture gained slightly less than the others, and the steers getting the arsenic-salt mixture made the best gains. The steers imported from a non-seleniferous area made as good gains as the native steers.

When the steers were started on the experiment the average of their weights on three consecutive days was used in dividing them into lots. The average weight of each lot then was: Lot I, 477.3 lbs.; Lot II, 476.0 lbs.; Lot III, 474.7 lbs.; Lot IV, 476.2 lbs. The group of native steers averaged 103.75 lbs. lighter than those in the imported group.

The first year the steers remained on the range until December 23, with no additional feed. They were put back into their respective pastures April 3, 1940, and remained on pasture until November 10. They were put into their pastures again April 8, 1941, and were not given additional feed until January 3, 1942. They were put back into pastures May 19, 1942, and remained there until they were sold on September 17, 1942.

The former U. S. Range Field Station at Ardmore is the nearest place at which controlled range studies have been made so data secured at this station have been used chiefly for comparison with our results. At Ardmore, the normal summer grazing season is considered to be from May 15 to September 15. Since our steers were weighed on the 21st of the month, we will consider May 21 to September 21 as the summer season in discussing results

As shown in figure 1, the growth curves of the steers exhibit definite trends. The steers all made good gains during the summer months and remained stationary during the winters. The first summer (June 21 to September 21) there was practically no difference in the gains made by each lot. However, soon after that the effect of the selenium in the grass seemed to become apparent and lots I and II failed to make further gains, while lots III and IV made good gains from September 21 to October 21.

The average gains of the steers in each lot from June 21 to September 21 were 96, 109, 97, and 109 pounds, respectively. Black et al. (1939) found that for three years the average summer gain for a three-month period was approximately 136 pounds. Thus the gains made were somewhat below what might have been expected on normal range although age of the steers may be a factor which needs to be considered.

The steers began the second grazing season (1940) in fairly good condition, as they had all made slight gains during the winter. As two-year

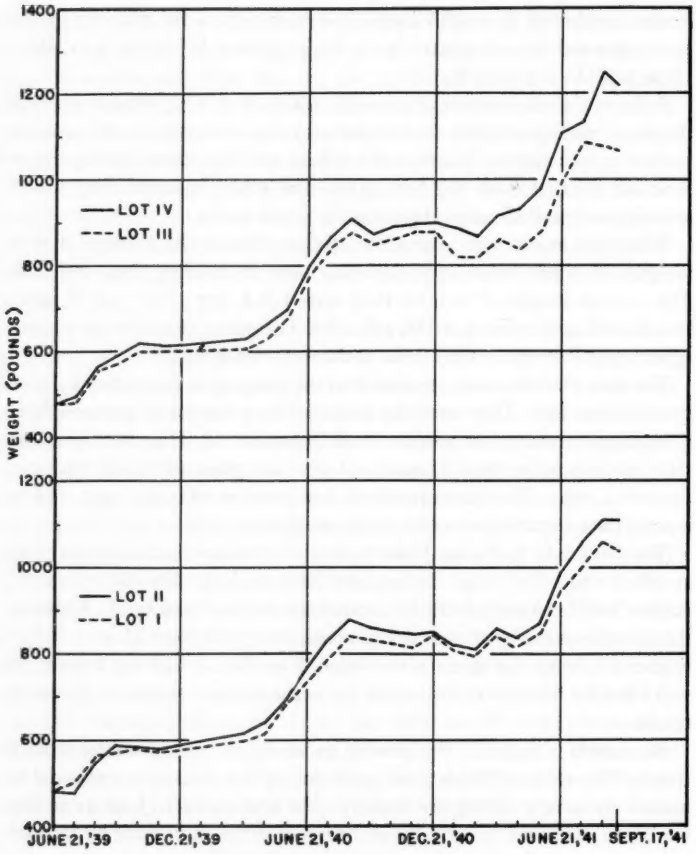

Figure 1. Growth curves of steers. Weights were taken on the 21st day of each month.
Lot I: 10 acres of range per head
Lot II: 30 acres of range per head
Lot III: 20 acres of range per head
Lot IV: 20 acres of range per head plus arsenic-salt

olds during the summer grazing season, the steers made very good gains. In September the two heaviest steers from each lot were sold to a packer. During the period from May 21 to August 21, the average gains of the steers in the four lots were 222, 235, 254, and 248 pounds, respectively. These

gains in 92 days compare favorably with the average gain of 280 pounds in 215 days observed by Black et al. (1939). Considering only the eight steers left in each lot on September 21, their average gains for the summer were 190, 206, 182, and 187 pounds for the four lots, respectively. Gains observed by Black et al. (1939) for a corresponding period were 162 pounds. Black and Clark (1938) observed the average summer gain for two-year old steers wintered on range at Ardmore, South Dakota, to be from 172 to 192 pounds. These workers found that the average selling weight for two-year old steers off pasture was 857 to 866 pounds. These weights are comparable with the September 21 average weights of steers in the four lots: 833, 866, 846, and 864 pounds.

On August 21, 1940 (the last weighing at the ranch), the weights of the steers which were sold were: Lot I, 987 and 1045; Lot II, 1020 and 990; Lot III 1010 and 1075; Lot IV, 1020 and 1097. Seven of the steers sold for $8.00 per 100 lbs., and one sold for $6.50 per 100 lbs. (this steer, from Lot II, was the smallest of the group and weighed 130 pounds less than the average of the other seven steers). Samples from each carcass were saved for selenium analysis.

From the 21st of August to the end of December, the remaining steers continued to gain slightly. However, through January and February they all lost weight. These months were quite cold but the steers were out grazing much of the time. During March the steers all made gains but dropped back in April. By May 21, Lot IV had gained more than was lost during the winter, and the others were only slightly below their weight at the end of the previous pasture season.

From May 21 to September 17, the four lots of steers gained 181, 233, 180, and 226 pounds, respectively. These weights are for the steers which had remained in the same lots throughout the experiment.

The steers were sold to a packer in September, 1942. The average weight of the steers in each lot and the average selling price per 100 lbs. (to the nearest 5 cents) and per head (as actually received) were:

Lot I	1043.9	$8.65	$ 90.53
Lot II	1020.5	8.70	88.69
Lot III	985.0	8.65	85.42
Lot IV	1165.0	8.95	104.16

Apparently the steers in Lot IV were slightly better in condition and appearance than the others and sold for the highest price per 100 lbs. The superiority of this lot was in its weight, which made the average price per head much higher than for any of the other lots. It was noted that the average initial weight of the four steers remaining in Lot IV was the same

as the average for the whole lot when they were started on the experiment, so their advantage in final weight was not due to greater initial weight.

One steer in Lot III had a severe lump jaw at the time of sale and weighed only 790 pounds. The average price per head for the other four was $90.48. In computing the average price per head ($85.42) of Lot III a deduction of $1.50 for the head of the steer with lump jaw was not considered. The light

TABLE 1. SELENIUM CONTENT* OF STEERS SOLD
AVERAGE OF LOTS

Lot	Organ				
	Blood	Kidney	Liver	Spleen	Meat
Steers sold September, 1940					
I	1.6	3.3	2.3	.6	1.0
II	2.4	2.3	.7	.8	1.3
III	1.8	1.3	.7	.5	.8
IV	1.0	1.9	1.1	.4	.5
Average	1.7	2.2	1.2	.6	.9
Steers sold September, 1941					
I	2.0	3.9	6.7	2.6	3.8
II	2.4	3.6	5.4	2.7	2.5
III	3.4	3.8	5.3	1.8	2.8
IV	.4	4.5	5.0	2.7	3.0
Average	2.05	3.95	5.60	2.45	3.03

* Selenium content in parts per million on fresh basis, i.e., normal moisture content.

weight of this steer can probably be accounted for by the lump jaw which had been chronic for several months.

When the steers were sold, samples of the carcasses were secured and analyzed for selenium. The average selenium content of representative tissues from the steers in each lot is shown in table 1. The tissues from the steers sold the second year contained considerably more selenium than corresponding samples from those sold a year earlier. Studies carried out by this laboratory have shown that eggs from seleniferous areas contain selenium in concentration similar to the concentrations found in the tissues from these steers.

Careful observations of the symptoms[7] of selenium poisoning were made

[7] Detailed descriptions of the symptoms of selenium poisoning have been published (Draize and Beath, 1935; Moxon, 1937).

Figure 2. Typical examples of cracked hoofs caused by selenium poisoning.

and recorded at seven different times during the course of the experiment. The symptoms appeared each summer or fall about the time the grass began to dry up as a result of hot, drying winds. The first noticeable symptom was lameness or stiffness of the forelegs. This was followed in a few weeks by a cracking of the hoofs at the growing point (figure 2). New growth of hoof started and eventually the old hoof became detached. By the end of the winter most of the symptoms had disappeared and by spring the steers were thin but in good condition otherwise. They gained during the spring and early summer and were free from symptoms of selenium poisoning until

TABLE 2. INCIDENCE OF SYMPTOMS AT VARIOUS DATES

Date	1939	1940			1941			Totals
	Nov. 21	Jan. 11	Sept. 1	Oct. 21	Jan. 21	July 28	Aug. 21	
Lot I	3C	4C	5C-1SL	4C	3C	—	1C	20C-1SL
Lot II	4C	8C	7C	6C	3C-2SL	—	1C	29C-2SL
Lot III	5C	4C	5C	4C	—-1SL	3C	1C	22C-1SL
Lot IV	2C	3C	3C*	—	—	—	—	8C—
Totals	14C	19C	20C-1SL	14C	6C-3SL	3C	3C	79C-4SL

* Arsenic content of salt for lot IV increased to 25 p.p.m. in July, 1940.
C = Cracked hoofs usually accompanied by stiffness and lameness (See figure 3).
SL = Stiff or lame but no cracked hoofs.

late summer or early fall. The incidence of symptoms in each lot is summarized in table 2.

The fact that the steers were sold about a month earlier in 1940 than in 1941 may be a factor contributing to the higher selenium content of the tissues from those sold in 1941, as it is in this period that the most severe symptoms appear. More extensive data are needed to clarify this point.

Summary

Steers were grazed on a highly seleniferous range for two years, starting as yearlings. The steers allowed slightly less than normal range per animal made the poorest gain but there was no marked advantage in allowing excess range.

Steers fed 25 p.p.m. of arsenic in the salt made the best gains and sold at a slightly better price than the others. Furthermore, the incidence of symptoms of selenium poisoning was reduced by this treatment.

The selenium content of organs and tissues was determined on samples taken at the time of slaughter.

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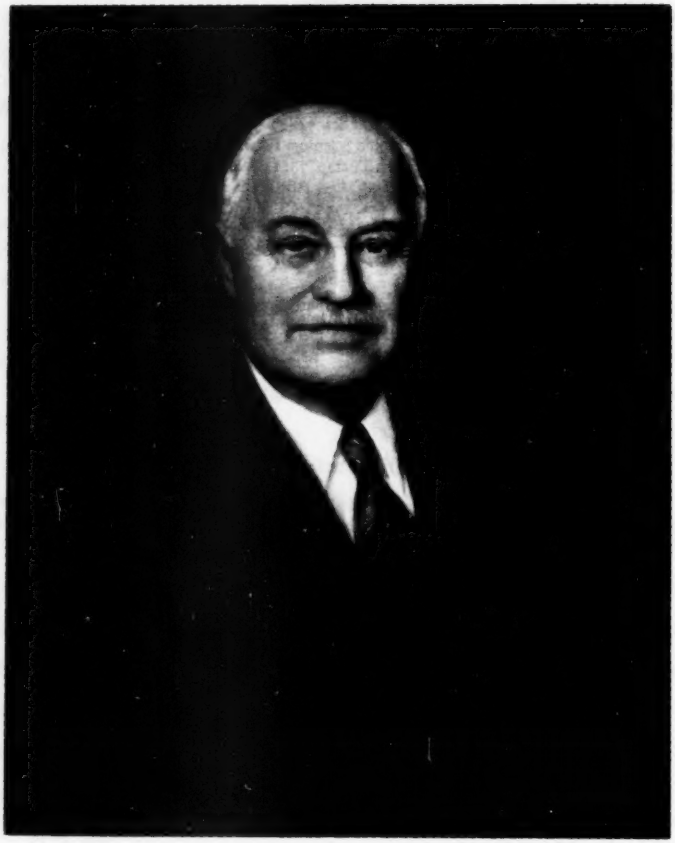

Harry L. Garrigus

Reproduction of a portrait presented to the Saddle and Sirloin Club by the American Society of Animal Production on November 30, 1943. Harry L. Garrigus was the Honor Guest of the Society during its annual meetings that were being held at that time.

HARRY L. GARRIGUS

Honor Guest—1943

Harry Lucian Garrigus was born at Wolcott, Connecticut, August 18, 1876. He entered Connecticut Agricultural College as a sophomore in 1895 and was graduated in 1898.

After graduation Mr. Garrigus remained at Storrs for a year as assistant to the veterinarian, Dr. Mayo. He spent a summer in charge of the dairy and livestock at an estate at Tarrytown, N. Y., and then joined the staff of the Baron Hirsch school at Woodbine, New Jersey. After a year he was called back to Storrs by Director Phelps as an assistant on the Storrs Agricultural Experiment Station staff. Before returning to Storrs he spent a period of advanced study of livestock problems at Ontario Agricultural College at Guelph.

From November 1, 1901, when he returned to Storrs, until his retirement forty years later, Professor Garrigus was intimately a part of the progress and growth of the institution, now the University of Connecticut. He became head of the animal husbandry department in 1907 when it was set up as a separate department. He remained for thirty years actively in charge of the college farm and acquired much of the land holdings that made possible expansion of the university.

Professor Garrigus is known as one of the keenest livestock judges in the country and has travelled widely throughout the United States to judge at fairs and shows. With little money to invest he built at Storrs herds and flocks of livestock of which any institution might be proud and which contributed in no small measure to the building of prestige for the university. Through counsel and encouragement he put life and vitality into the New England livestock industry.

As officer, director or member he has contributed to local and national organizations for livestock improvement including: Percheron Society of America, American Berkshire Association, Milking Shorthorn Society, American Devon Cattle Club, Connecticut Sheep Breeders' Association, Connecticut Dairymen's Association, Connecticut Swine Growers Association, American Genetic Association, American Society of Animal Production and Eastern States Exposition. He has been national president of Lambda Gamma Delta.

Professor Garrigus is a member of the Congregational Church, a thirty-second degree Mason, a Rotarian, and has been active in other civic affairs. His son, Wesley, is head of the Animal Industries Group at the University of Kentucky.

NEWS AND NOTES

The thirty-seventh annual meeting of the American Society of Animal Production will be held at the *Morrison Hotel* in Chicago on December 1 and 2, 1944, according to present plans, with a dinner for the honor guest at the Saddle and Sirloin Club at noon on December 3. Titles and abstracts of papers to be presented at these meetings must be in the hands of the Secretary, Dr. W. V. Lambert, Purdue Agricultural Experiment Station, Lafayette, Indiana, by September 10. Titles received after this date cannot be included in the program and abstracts cannot be published. Abstracts, to appear in the November issue of the JOURNAL OF ANIMAL SCIENCE, must not exceed 250 words. Longer abstracts will be reduced arbitrarily by deletion of material at the end. Chairmen of the sectional meetings are listed below:

Animal Breeding	Ralph Bogart, Missouri
Beef Cattle	Rex Beresford, Iowa
Dairy Cattle	H. P. Davis, Nebraska
Extension	Claude Harper, Indiana
Horses and Mules	R. B. Cooley, Indiana
Meats	J. M. Ramsbottom, Swift & Co., Chicago, Illinois
Nutrition	R. C. Miller, Pennsylvania
Pasture and Range	R. H. Lush, National Fertilizer Co., Washington, D. C.
Sheep and Wool	R. F. Miller, California
Swine	L. L. Madsen, U. S. D. A.
Teaching	J. S. Coffey, Ohio

John V. Christensen, formerly of the Branch Agricultural College, Cedar City, Utah, has been appointed assistant professor of animal husbandry at the Utah State Agricultural College, Logan.

Stanley Smith, formerly of the U. S. Range Sheep Experiment Station, Dubois, Idaho and recently with the Farm Credit Administration in Washington, has resigned to take charge of his father's ranch near Gooding, Idaho.

C. L. Forsling of the U. S. Forest Service has been nominated by the President as director of grazing under the Taylor Grazing Act, to succeed R. T. Rutledge who recently resigned.

V. A. Freeman, of the animal husbandry staff at Michigan State College, has been appointed assistant State leader of Four-H club work, in charge of livestock projects, at the same institution.

W. L. Richmond, formerly assistant county agent at Clarksdale, Mississippi, is now assistant extension animal husbandman at Mississippi State College.

H. M. Stamey is now assistant in animal husbandry extension at the North Carolina State College.

Russell A. Rasmussen, formerly associate chemist at the Michigan Agricultural Experiment Station, is now with Hiram Walker and Sons, Peoria, Illinois, where he will conduct research on the utilization of distillers' by-products in animal feeding.

Kenneth C. Ikeler, superintendent of the Squaw Butte-Harney Range and Livestock Station, Burns, Oregon, has been appointed regional grazier for the Department of the Interior, with headquarters at the same address.

Fred F. McKenzie, formerly head of the animal husbandry department at Utah State Agricultural College, will join the animal husbandry staff at Oregon State College in Corvallis on October 1, 1944, as professor of animal husbandry.